THE SURGICAL CLINICS OF NORTH AMERICA

JUNE 1973

PERSONAL PREFERENCES IN SURGERY

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SYMPOSIUM ON
PERSONAL PREFERENCES IN SURGERY

Harry S. Goldsmith, M.D.
Guest Editor

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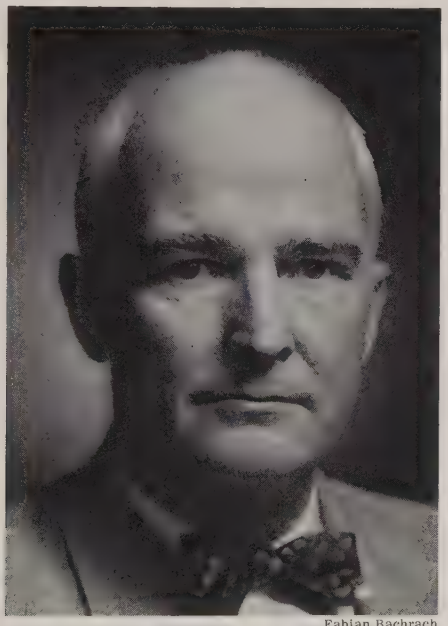
Foreword

The Department of Surgery of the Jefferson Medical College is indebted to the Saunders Company for the opportunity to prepare this issue of the *Surgical Clinics of North America.* In this symposium, various members of the surgical staff at the Thomas Jefferson University Hospital and at other hospitals associated with the Jefferson Medical College have described their personal preferences in performing a



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JOHN H. GIBBON, JR., M.D.

variety of operative procedures. Many of the authors were directly involved with or indirectly influenced by the late Dr. John H. Gibbon, Jr., who developed the heart-lung machine and served as the Samuel D. Gross Professor of Surgery at the Jefferson Medical College from 1956 to 1967. It is to Dr. Gibbon that we respectfully dedicate this volume. The presence of his imagination and accomplishments will remain as long as the ledger of surgery remains open.

HARRY S. GOLDSMITH, M.D.

Guest Editor

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Personal Preferences in Anesthesia

*Jay Jacoby, M.D.**

Anyone who administers anesthesia is an anesthetist. There are now physician specialists who are called anesthesiologists, as well as nurse anesthetists, dentists, and others who are called anesthesia technicians. We will use the term "anesthetist" to include all these individuals.

Many anesthetists consider their specialty to be a completely independent entity, and a medical specialty rather than a surgical one. I think anesthesiology is very closely related to surgery and that it should be considered a surgical specialty. One would not normally be the patient of an anesthetist unless he were also the patient of a surgeon. With the exception of the relatively recent additions of resuscitation, respiratory care, and pain control, all the endeavors in anesthesia relate to surgical operations. The task of the anesthetist is to keep the patient in good physical condition and free of pain, and to make it as easy and as safe as possible to carry out a surgical operation.

The Surgeon's Involvement with Anesthesia

Surgeons are very properly concerned with anesthesia. Without them, the need for anesthesia would not exist. For many years anesthesiology grew under the shelter of and with the encouragement of the surgical profession. To reciprocate, anesthesiology has made possible many of the advances for which surgery receives high praise.

The surgeon's concern with anesthesia has both a moral and a legal basis. When a patient agrees to have an operation he looks to the surgeon for the safety and propriety of the actions of all other individuals concerned with that operation. The patient expects the surgeon to see to it that there is no problem with the anesthesia. The surgeon is expected to recognize when something is going wrong with the anesthesia, and to be able to make recommendations for its correction. Most patients do not realize that anesthesiology has grown into a separate specialty. Indeed, many of us tend to forget that about half the anesthetics in the United States are administered by nurses, for whose actions the surgeon is di-

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rectly responsible. If something goes wrong with the anesthesia and a lawsuit results, the surgeon is likely to be named in the lawsuit along with the anesthetist. Changes in attitude as to the responsibility of the surgeon and the physician anesthetist are still developing in the courts. The recent legal decisions that physician anesthetists do have serious responsibility have caused their malpractice insurance to become as expensive as any surgeon's.

This article is not designed to be a textbook of anesthesia for surgeons. Instead, it presents my beliefs about certain aspects of anesthesia with which surgeons are concerned. It takes for granted that the surgeon already has a substantial amount of basic information.

Dangers of Anesthesia

Whenever a patient receives an anesthetic his life is in jeopardy. Even a local anesthetic for a minor operation may result in a fatality. Most deaths associated with the use of anesthetics are preventable. They result not from allergy or idiosyncrasy to drugs, but from errors of omission or commission, from lack of knowledge, or from improper or delayed response to problems which arise during the course of the anesthetic. Cardiac arrest during anesthesia is not merely an act of God, but is the end result of an unphysiologic sequence of events. Cardiac arrest is usually preventable.

Every physician should bear in mind that anesthetics are poisons and that there is a significant morbidity and mortality related solely to the anesthesia, and not to the operation. In a hospital where there are 20,000 operations per year, it is likely that anesthesia kills one patient every month. If this fact were given proper consideration, the attitudes of the public and the medical profession toward anesthesia would be significantly altered.

PREOPERATIVE CONSIDERATIONS

Preoperative Visit

Most surgeons and many anesthetists think that the preoperative visit by the anesthetist is made for the purpose of selecting and ordering the preoperative medication. That is only partly true. The more important purpose of the preoperative visit is the detection and prevention of future trouble.

The anesthetist reviews the history and the physical findings. He queries the patient for specific items of medical history which are likely to be omitted in a general work-up. He may perform a physical examination of limited or major extent, to determine or verify physical factors related to the anesthetic. In the preoperative visit, the anesthetist elicits all those factors of history and physical findings which relate to the possibility of problems arising during anesthesia and operation. These include previous experience with anesthetics, current illnesses and medications, and alterations of body structure or function.

The preoperative visit ordinarily is made the day before operation.

The anesthetist should determine the adequacy of the patient's work-up at this time, and if there are any omissions he should see to it that they are corrected. It should not be necessary to cancel an operation on the morning of surgery simply because of an omission in the work-up which could have been detected and corrected the day before.

Informed Consent

The anesthetist should tell the patient as little as possible. This seems somewhat paradoxical and I explain it in the following way: The patient has already made up his mind to undergo the operation. The surgeon has discussed with him all the risks and all the things that may go wrong. He has come into the hospital prepared to proceed. If the surgeon and patient have decided to use local anesthesia, usually the anesthetist is not involved at all. The anesthetist having been called in, however, a detailed presentation of the risks of anesthesia can only alarm the patient. He really has no alternative but to undergo anesthesia. The only option available to him is whether he is to have general or some form of regional anesthesia. Indeed, the anesthetist should not present the patient with such an option. The anesthetist should decide what is the best anesthesia, and tell the patient what he has decided to be the optimum anesthetic for this operation. Only if the patient objects to the type of anesthesia should an alternative be discussed. Only if the patient raises questions regarding complications of anesthesia should they be discussed.

This is a somewhat cavalier attitude toward the doctrine of informed consent. The fact is that informed consent is interpreted differently for each case. It is recognized that not all patients should be told all about all the potential complications. Perhaps they should be told only about those which are likely to occur. There are those who feel that this is inadequate to allow the patient to give informed consent. If so, the patient should be given this information, and allowed to consider it, before deciding whether to have the operation and before his admission to the hospital. If that be the case, a sensible solution of the problem is to give the patient the information regarding anesthesia when he visits the surgeon's office. Two brief brochures are available for distribution to prospective surgical patients, giving some information about the methods and possible complications of anesthesia. These are distributed by the American Society of Anesthesiologists and are available from them in bulk quantities. For the patient who is seriously concerned, an interview with the anesthetist should be arranged before the decision is made, and before the patient is hospitalized.

Of course, if any patient wishes to have detailed information, it should not be withheld.

Anemia

One of the principal items which the anesthetist looks for on preoperative rounds is the blood count. In many hospitals, certain levels of hemoglobin, hematocrit, or red count have been established as the minimum acceptable values prior to surgery. If a patient has a level below the

acceptable limit, the first sensible move is to have the test repeated, since it may be only a laboratory error. If the low value is confirmed, the surgeon has three options: to send the patient home with replacement therapy and wait for nature to form more hemoglobin; to give a blood transfusion to bring the values up to a more acceptable level; or to proceed without correcting the anemia.

I believe that to delay is often impractical, and that transfusions have significant potential hazards. In many instances we should proceed with the anesthesia and the operation without correcting the low level of hemoglobin or hematocrit, particularly if it is a minor operation. There is no specific number which is a minimum acceptable limit. The danger of anemia in the surgical patient has been exaggerated.

The purpose of the hemoglobin is to carry oxygen to the vital structures, and patients with moderate anemia have enough hemoglobin to do that. Their margin of safety is reduced, however, if any serious problem arises during the anesthesia and operation. In the anesthetized state, patients are offered a higher concentration of oxygen than they get when they breathe air, and at the same time they have a lower metabolic rate, so that they need less oxygen. If the patient can function in his normal activities while he is anemic, he should be able to function equally well while anesthetized. The important thing about a low hemoglobin or hematocrit is to determine why it exists, as it may be the result of a serious but undiagnosed disease.

Blood Volume

In the anesthetized patient blood volume is of far greater importance than the hemoglobin level. Depleted blood volume predisposes to "anesthetic shock." Since blood volume determinations are not commonly carried out, and since hemoglobin and hematocrit readings are likely to be misleading, an important consideration is the patient's body weight. If a patient has lost a significant amount of weight without being on a weight reducing diet, it is likely that he has a depleted blood volume. Such a patient would benefit by preoperative transfusions of up to one pint for each 10 pounds of weight loss which occurred during the preceding year. Blood fractions may be indicated.

Cortisone

The administration of cortisone tends to cause adrenal suppression and inability to respond to stress. If a patient is taking cortisone regularly before operation, the dosage of the cortisone preparation should be increased before, during, and after the operation. For those patients whose cortisone administration had been discontinued within the previous 6 to 12 months, it is customary to re-establish cortisone therapy on a prophylactic basis, because the adrenal suppression is prolonged.

I believe that this is unnecessary. It is a relic of the days when no preparations of cortisone were available for rapid administration. I believe the prophylactic cortisone should be omitted. Cortisone preparations are potent drugs which do have harmful effects. The great majority of patients do not require this treatment, and will suffer no harm by the

omission. For the few patients who develop symptoms of adrenal insufficiency during or after operation, treatment can be immediately administered intravenously. Needless therapy will have been avoided for large numbers of patients.

Antihypertensive Drugs and Tranquilizers

These are taken by many individuals who are candidates for surgery. When anesthetized, such patients sometimes develop hypotension. It has therefore been recommended that such medications be discontinued for a sufficient length of time to allow the effects of the medication to disappear.

I believe that this is undesirable and unnecessary. If a patient needs tranquilizers or antihypertensive drugs ordinarily, he is likely to need them even more at the time when he approaches a surgical operation which he may regard as a critical experience in his life. I believe the patient's medication should be continued right up to the time of operation, unless a less hazardous but effective drug can be substituted. The anesthetist and surgeon should be aware of the fact that such patients may develop hypotension during the operation, and that such hypotension may be either refractory to therapy, requiring more drug than expected, or very sensitive to therapy, requiring much less drug than expected. Careful titration with a vasopressor drug in an infusion bottle will keep the patient's blood pressure within the desired range.

Sympathetic Blocking Drugs

Medication with alpha blocking drugs produces peripheral vasodilatation. The physician must be sure that the patient is well hydrated and that his blood volume is normal, otherwise severe hypotension may occur. Examples include phentolamine, phenoxybenzamine, and the tranquilizers thorazine and droperidol.

Beta blocking drugs (propranolol) are now frequently encountered in preoperative patients, being used for treatment of angina or cardiac arrhythmias. Under anesthesia these patients may develop hypotension, bronchospasm, and congestive heart failure. The specific medication to counteract these effects is isoproterenol. There has not been sufficient experience to predict how often these problems will arise or how difficult they will be to treat. Therefore, if possible, the drug should be discontinued before operation. Since it has a short duration of action, if it is discontinued one day before operation, the likelihood of adverse residual effect is negligible.

Premedication

There are two principal reasons for giving premedication: to sedate the patient, and to prevent undesirable responses to anesthesia and surgery. Premedication should be given with sufficient lead time to be certain that it is absorbed and becomes effective—about an hour. When the time for operation is uncertain, the medication should be given too early rather than too late. In the former instance it can be repeated; in the latter, there would be no effect. Intravenous administration should be

considered. Large numbers of sedative type medications have been introduced in recent years, and the advertising for these drugs has confused physicians as to what should be used.

For local anesthesia, the surgeon should order a sedative drug which also has anticonvulsant properties, since toxic reactions to the local anesthetic drugs may be manifested by convulsions. The barbiturates and diazepam (Valium) are suitable drugs. No atropine or other belladonna drug should be used because it would contribute only the discomfort of a dry mouth.

For general anesthesia, sedation should be provided by a narcotic whose analgesic property will also be useful in diminishing the amount of general anesthetic agent required. This use of narcotics is sometimes frowned upon, because they are also respiratory depressants. Judicious adjustment of dosage is all that is required. In addition, the patient should be given a belladonna drug which serves the purpose of drying secretions and diminishing vagal reflexes. Although scopolamine is a better drying agent, it sometimes produces psychologic effects which are undesirable. Atropine serves equally well as a drying agent merely by increasing the dose, and atropine has the added advantage that it controls bradycardia and other vagal reflexes better.

CHOICE OF ANESTHESIA

Safety should be the main concern. We sometimes lose sight of this fact and allow other considerations to play a determining role. These secondary considerations include pleasantness, speed of induction and emergence, and absence of nausea and vomiting in the postoperative period.

The best anesthetic for a particular patient should be chosen by elimination. Discard the most hazardous methods and agents. To put it another way, select the least hazardous method and agent. Only when several methods and agents provide equal safety for the patient, should the secondary factors be allowed to enter the picture and influence the choice.

Who should select the anesthetic? Selection should be made by the individual who is going to administer the anesthetic. The most important item in his consideration should be his familiarity with the method or agent, and his ability to deal with it in such a way that it becomes the safest, for this operation, for this patient. Theoretical considerations relating to the virtues of other agents or methods, with which the individual anesthetist is not familiar, should be disregarded. There is virtually no theoretical consideration which takes precedence over the skill and experience of the person who is to administer the anesthetic. For example, because of its disadvantages, chloroform has been almost universally discarded. Yet, if I myself needed to have an anesthetic, and the anesthetist available was an expert with chloroform but nothing else, I would have chloroform.

When the anesthetist is called in, he first decides whether the procedure should be done under regional or general anesthesia. His choice is based upon his evaluation of the patient, the proposed operation, and his knowledge of the alternatives available. He should pick that alternative which can best satisfy the first requirement of safety, and also possesses the secondary attributes which lead to acceptability by the patient and by the surgeon. If the anesthetist is expert in all methods, and the patient and operation make any method appropriate, my choice in descending order of desirability is local, nerve block, spinal, epidural and general. Considerations of practicality, surgeon's desires, and patient acceptance as well as informed consent, frequently cause this order to be reversed.

The patient should have a voice in the selection of the anesthetic. All other things being equal, if the patient has a specific request regarding the use of an agent or method, it should be honored, even if it is based on erroneous information. However, if the patient's choice would be deleterious to him, he should be told why, and what the better alternative would be. A specific consent should then be obtained. If the patient cannot be convinced as to the use of a safe and appropriate anesthetic, the anesthetist may withdraw from the case. He cannot be compelled to do something which he thinks is contraindicated. Such a situation should arise only once in a lifetime.

Spinal Compared to Epidural and Caudal

If a major regional block is to be used to anesthetize a large segment of the body, spinal, epidural and caudal are interchangeable. They produce the same effects. Sensory, motor and autonomic blockade occur with each, but more rapidly with spinal. A local anesthetic drug is applied to the nerves inside the dural sac in the first type, or in the space between the bony canal and the dura in the others. With caudal and lumbar epidural, the drug enters the same epidural space through different openings in the bony canal. The continuous technique can be utilized with any of these methods.

I think spinal and epidural anesthesia are particularly appropriate for elderly patients and for operations on the perineum and legs. They are also satisfactory for intraperitoneal operations if ample sedation is given and if the level is high enough to block both the somatic and the visceral afferent nerves. They are often used for women having obstetrical deliveries, because patients in pain accept any form of pain relief, their use can be extended for a prolonged period, and because they are better for the fetus than general anesthesia.

The three methods have adverse effects in common: hypotension and respiratory paralysis. Treatment is straightforward: fluids and vasopressor drugs for hypotension, and artificial respiration for respiratory paralysis.

Spinal anesthesia has one drawback not shared by the others: the headache which may follow dural puncture. But when epidural anesthesia is attempted, inadvertent puncture of the dural sac may also occur. Since the needle used for epidural is much larger, it makes a

bigger hole in the dura and there is a greater likelihood that a dural puncture type of headache will follow.

Epidural and caudal anesthesia have drawbacks not shared by spinal: they are more time consuming, there is a higher incidence of failure, there is less certainty in predicting the level. For epidural and caudal the doses of drugs used are much larger, so that there is a greater likelihood of systemic drug reactions, and inadvertent intrathecal injection may cause total spinal anesthesia. The last two increase the mortality.

Given a free choice, I select spinal anesthesia in preference to epidural.

The Value of Local Anesthesia

As an exception to the points made above, that the anesthetist should select the method and agent to be used for anesthesia, the surgeon should choose local anesthesia frequently without involving the anesthetist at all.

I believe that local is the safest method of anesthesia available. If I needed to have an operation, it would be done under local anesthesia, if at all possible. And it is possible far more often than we acknowledge in our daily thinking. In fact, I would tend to put myself, as an anesthetist, out of business.

Many operations can be done under local anesthesia, but other methods are selected for several reasons. Patients wish to be asleep during their operations. Local anesthesia is time-consuming. It is often incomplete. The patient frequently suffers some discomfort and he may become uncooperative. Muscle relaxation may be inadequate. The handling of tissues must be more gentle to avoid triggering undesirable reflexes. The duration of anesthesia may be inadequate for the procedure. The quantity of anesthetic drug required may be excessive and lead to toxic reactions.

Most of these drawbacks can be overcome. Careful explanations to the patient should make him receptive to local anesthesia, and appreciative of the surgeon's concern. Sedation given before or during the operation can diminish the patient's apprehension and alertness, to the point that he can be entirely unaware of the operation. The operating room should be quiet and dignified. An anesthetist should sit with the patient, both to monitor his physical condition, and to administer such medication as may be indicated.

The surgeon should select the drug for local anesthesia on the basis of its relative absence of toxicity and its duration of action. For short procedures, xylocaine and procaine are suitable; for long procedures, carbocaine, pontocaine or nupercaine are reasonable choices. They should be used in the minimum effective concentration so that the total number of milligrams administered is well within the maximum dose. The addition of a vasoconstrictor, if the patient's physical condition permits, helps to retard absorption, diminish toxic reactions, and prolong the duration of anesthesia.

TECHNICAL ASPECTS

Before Anesthesia is Begun

The patient should be positively identified, by asking his name and by checking his identification bracelet. This should be done by the operating room nurse and the anesthetist. The surgeon should also say a few words to the patient, both to identify him and to reassure him that he is present and that all will go well. In any case, the anesthetic should not be started until the surgeon is present; he might be delayed or incapacitated and unable to communicate.

It is customary to have patients remove all dentures before coming to the operating room. This is done because the dentures may break, and fragments may become foreign bodies in the respiratory passages. There is little likelihood of this happening. I prefer that dentures be left in place during anesthesia, because they fill out the normal contours of the face, and make it easier to maintain an airway and maintain the fit of the mask. Of course, if the patient is to have an endotracheal tube inserted, the dentures should be removed.

Almost all patients who come to the operating rooms have intravenous infusions. It is easier to maintain a prolonged intravenous infusion when a plastic catheter is used. However, such catheters may break and form emboli, or when left in place for a long time they may cause phlebitis. For patients who require prolonged intravenous therapy, plastic catheters provide a comfort and convenience, but at some risk. Patients who are having minor operations do not need prolonged intravenous therapy, and a steel needle is quite adequate for the intravenous infusion which the anesthetist wishes to administer during the operation. Although the steel needle is more likely to infiltrate, it is safer and should be the method of choice unless there is a real reason for using a catheter.

Monitoring

The simple means of determining the patient's condition should not be neglected. These include determination of arterial blood pressure, palpation of the pulse for rate and rhythm, observation of the respiratory rate, depth and rhythm, the color of the skin, mucous membranes and the blood, and determination of the patient's temperature. These require only the use of the senses and simple devices. They provide information of great value, and without risk. Because of their simplicity, their value is often underestimated.

A precordial stethoscope placed on the left side of the chest allows the anesthetist to hear both the heart sounds and the breath sounds of the left lung. If unilateral atelectasis is to occur, it is most likely to occur on the left side. It can be detected with a left chest piece, whereas it cannot be detected with an esophageal stethoscope. The esophageal stethoscope is popular because it gives loud and clear heart sounds and breath sounds. But it does not allow the anesthetist to determine whether the breath sounds are coming from one or both lungs. An endotracheal tube

which is down too far would not be detected with an esophageal stethoscope, but it would be with a left chest piece.

Audible pulse monitors are a convenience and a comfort to the anesthetist and surgeon.

EKG monitoring undoubtedly demonstrates the development of arrhythmias earlier than other methods. EKG monitoring introduces drawbacks: distraction of the anesthetist who attempts to correct instrument malfunction, and an increased possibility of electrocution of the patient. There are few instances when EKG monitoring is of real value to patients, but I think that it is a real hazard, because of distraction, in many more instances. During an operation, if anything goes wrong with the electrocardiographic instrument, the anesthetist should resolutely avoid trying to correct it. He should call for another individual to do this. We await the development of more stable instruments.

The determination of central venous pressure has become popular. The information obtained from a central venous pressure catheter is little different from that obtained from a peripheral catheter. It is not the absolute reading, but the change, which is important, and both change in a parallel manner. The peripheral catheter reading tends to be a little higher. The central venous catheter has a number of drawbacks compared to the peripheral catheter, including the possibility of causing a pneumothorax, when the subclavian approach is used. Bilateral pneumothorax has occurred. If the central catheter is inserted at the cubital fossa there may be mechanical obstacles to its passage into the superior vena cava, and indeed it may end up in some other venous tributary. A central venous catheter may cause cardiac arrhythmias and may perforate the heart and produce pericardial tamponade.

Neuromuscular response is of special interest in patients who have received large doses of muscle relaxant drugs. We must not lose sight of the fact that in such patients the concern is not whether the finger twitch is back to normal, but whether the patient's ability to breathe is back to normal. The most important observation is, therefore, not the neuromuscular response to electrical stimulation, but whether or not the patient can take a deep breath and give a vigorous cough.

GENERAL ANESTHESIA

Choice of Drugs

General anesthesia should be maintained with the most innocuous drugs available. Very marked changes have taken place in the preferences of anesthetists. The present situation is that explosive agents are rarely used: ether, cyclopropane, ethylene, ethyl chloride, and vinyl ether in many hospitals are no longer used at all. It is even proposed that new hospitals be built with no antiexplosion provisions in their operating rooms, and that explosive anesthetics be banned. There are few occasions when the use of an explosive agent is really necessary. I suggest that new hospitals be built with only one or two operating rooms prepared for

explosive agents, and that the savings of simpler construction in the other operating rooms be utilized for more important items.

Nonexplosive halogenated hydrocarbons, administered by inhalation, have been very popular. The possibility that these drugs may produce visceral damage has sharply curtailed their use, even though such damage occurs rarely. There is good evidence that kidney damage is caused by methoxyflurane, and is dose related. Deep anesthesia for a prolonged period is more likely to produce kidney damage than a short exposure. Concomitant administration of tetracycline increases the possibility of kidney damage. Oxalate crystals may be formed and parenchymal degeneration may occur. There may be high output kidney failure, characterized by excretion of several liters per day of dilute urine, or oliguria. In either case treatment consists of careful monitoring and replacement of fluid and electrolytes. That liver damage may be caused by either methoxyflurane or halothane is less well documented; if it does occur, it is probably due to sensitization rather than toxicity. In most cases postoperative liver damage is caused by shock, blood transfusion, or other obvious causes. Rare instances of liver damage, with no other known cause, are attributed to halogenated anesthetics. In these cases the development of an allergy to the drug is postulated, since there are usually repeated administrations and the effect is not dose dependent.

Dissociative anesthetics have effects different from those of typical general anesthesia. Innovar is a combination of a short-acting, potent narcotic, fentanyl, and a long-acting tranquilizer, droperidol, which produces "neurolept analgesia," in which the patient is relatively immobile, insensitive to pain, detached from his surroundings, and yet responsive to commands. Neither circulatory nor respiratory depression is supposed to occur. Unfortunately they sometimes do, if a sufficient dose is given to make operation possible. When other agents are given in addition to Innovar, such as nitrous oxide, the condition is called neurolept anesthesia, and is not much different from standard anesthesia. The recovery time may be prolonged.

Ketamine is also different from standard anesthesia in that the patient is dissociated from the environment rather than anesthetized, with the pain conduction and perception system selectively depressed. It is claimed that the use of ketamine ensures airway patency and that no depression of respiration occurs. Unfortunately this is not always true, and serious trouble may result if one relies upon this drug in this way. Other principal drawbacks to its use include the facts that patients develop hypertension, there are disconcerting random movements during operation, and the postoperative period may be accompanied by bad dreams or hallucinations or irrational behavior. The value of this drug has still to be determined.

If we eliminate the explosive agents, reduce the use of halogenated hydrocarbons, and only rarely use dissociative anesthesia or neurolept analgesia, what kind of anesthesia shall we give? Most anesthetists and I usually choose a balanced anesthesia technique which consists of the administration of several drugs. Induction is with thiopental, followed by

nitrous oxide mixed with enough oxygen to maintain superior oxygenation (30 to 50 per cent). Additional increments of either thiopental or a narcotic are administered at intervals during the operation, as indicated by the signs of light anesthesia. A muscle relaxant drug is administered in a sufficient dose to provide for the relaxation needed by the surgeon. Since the muscle relaxant also reduces the amount of anesthetic agent needed, regardless of the nature of the surgery, it is used in many patients for this purpose even if surgical relaxation is not required. I believe that these are probably the most innocuous of all the drugs which may be used to produce anesthesia, and that this combination is applicable in the great majority of all patients who need surgery. These drugs produce no visceral damage, no explosion hazard, no tendency toward cardiac arrhythmias. They tend to produce mild hypotension, and in most cases do produce respiratory depression. Both of these side effects can be counteracted with ease.

Endotracheal Intubation

At one time limited to patients with special indications, endotracheal intubation has now become commonplace. It is used for the convenience of the anesthetist, rather than for the needs of the patient. It takes skill and work to maintain a patent airway without an endotracheal tube. Some anesthetists have not developed the skill and others do not feel it necessary to do the work. There is no question that in some instances endotracheal intubation is imperative and lifesaving. But in other instances it may introduce problems which otherwise could be avoided. Among these are trauma to the lips, teeth, pharynx, and larynx. Delay in getting the tube in is a cause of asphyxia. When the tube is inserted, it may go into the esophagus. If inserted too far into the trachea, it enters the right bronchus, producing atelectasis of the left lung. The inflated cuff may produce damage to the mucous membrane of the trachea. Postoperatively the patient may have pharyngitis, laryngitis, or laryngeal edema. As a late development there may be a laryngeal granuloma.

Death as a result of endotracheal intubation may come about because of difficulty in inserting the tube, leading to immediate asphyxia, or because of laryngeal edema in the immediate postoperative period. Death from potassium poisoning occurs rarely, as a result of the administration of succinylcholine to obtain the relaxation needed for the intubation. Succinylcholine causes a release of potassium from muscle cells, and in most patients an inconsequential rise in the serum potassium level is produced. A very marked rise in serum potassium, causing death, may occur in the following types of patients: those with massive tissue trauma, with burns, and with major neurological disease leading to muscle atrophy. The danger period begins 7 to 10 days after the initial injury and continues for a variable period up to several months. It is safe, however, to use succinylcholine for the newly injured individual.

Endotracheal intubation should be considered as a potentially serious hazard or a potentially life-saving procedure. Between these extremes, intubation offers conveniences and advantages, as well as disadvantages.

Whether it should be used in a particular instance deserves a serious weighing of the pros and cons.

Spontaneous versus Controlled Respiration

The opinion of anesthetists is that all patients under general anesthesia have respiratory depression, with reduced minute volume, and therefore require assistance of their breathing. This usually leads to lowering of the P_{CO_2} below the threshold level, and the induction of apnea due to respiratory alkalosis. Pulmonary ventilation is then maintained either by a mechanical ventilator or by compressing the breathing bag. The advantages of this arrangement are: the anesthetist can be sure that there is adequate pulmonary ventilation, regardless of the amount or type of medication administered; a smaller amount of anesthetic drug is needed; and the patient awakens more quickly after operation. There are several disadvantages: endotracheal intubation is almost mandatory, otherwise the stomach becomes distended with gas; there is decreased blood flow to the brain and to the pregnant uterus; some of the signs indicating depth of anesthesia are lost. It is possible that a patient may be awake but paralyzed during his operation. The opposite may also occur, that the patient may be given an excessive dose of medication, leading to adverse effects during the operation, cardiac arrest, or prolonged effects after the operation is over.

If the patient maintains spontaneous respiration, the depth of anesthesia is more easily determined, and this tends to be an assurance against overdosage or underdosage of paralyzing drugs or potent inhalation anesthetics. I believe that some of the hazards of modern anesthesia are directly related to controlled respiration, and that whenever possible, a patient should be permitted to maintain significant spontaneous respiratory activity.

Early Awakening

Some proponents of the apneic technique advise its use on the basis that a smaller quantity of anesthetic agent is needed, that lighter planes of anesthesia can be used, and therefore the patients awaken more quickly after the operation.

The anesthetist who has his patient awaken on the table prides himself upon his technical ability. Of what advantage is it to have the patient awaken on the table? The dangers of obstruction of respiration, and aspiration of vomitus are reduced, and if such problems occur, they do so while the anesthetist is in attendance and can take care of them. Having the patient awaken on the table is of particular advantage especially in hospitals where there is no recovery room, and where postoperative care is not as good as it might be.

As far as the patient is concerned, he would much prefer to be asleep for a longer period. In institutions where recovery rooms are in use, or where there is good supervision of the immediate postoperative period, the advantage of having the patient awaken on the operating table is to some extent nullified. There is no great harm done if the patient is unconscious for a few extra minutes.

The disadvantages of having the patient awaken on the table are also to be considered. During the last part of the operation, the anesthesia is so light that the patient may move, cough, strain, or vomit. These events interfere with the surgical procedure, and are a cause of embarrassment to the anesthetist. In addition, the patient frequently remembers awakening in the operating room and he thinks that there was inadequate anesthesia administered. Early coughing and straining by the patient, before the dressings are in place, have been blamed by surgeons for wound dehiscence and evisceration, because of tearing of sutures or tissues before the wound is properly supported. While this is probably not true, it does remain as a criticism which is not easily overcome.

I believe that the patient should be kept unconscious and immobile until the operation ends, that he should not be allowed to awaken abruptly on the operating table, and that enough narcotic should be used at the end of operation to make the return of consciousness reasonably comfortable.

Postoperative Ventilatory Support

The importance of supplementary oxygen in the immediate postoperative period is well established. After major surgery, prolonged operations, hyperventilation, large doses of relaxants, and for patients with lung disease, humidified oxygen should be administered.

Some of these patients are unable to breathe adequately, and require continuous controlled ventilation. The ventilator must be connected to the patient through an endotracheal tube or a tracheostomy. The benefits must be balanced against the possibility of complications: equipment malfunction, dislodgment or obstruction of the tubes, infection. Each patient in this group also requires constant and expert nursing care. I believe that we should make every effort to avoid prolonged postoperative controlled ventilation, and that tracheostomy is preferable to prolonged use of an endotracheal tube.

CONCLUSION

The many advances in anesthesiology, in new drugs, techniques, and equipment, are impressive. They have made it possible to carry out safely, operations of great complexity. For the average patient, these advances superficially seem to be great improvements, offering pleasantness, speed, and freedom from postoperative effects. However, the equipment is more complicated, the controls are more delicate, the signs of depth are more difficult to read, and the possibilities of error are therefore increased. I believe that the advances in anesthesiology have increased the potential for accidental fatalities. It takes more knowledge and more skill than ever before, to provide the patient with safe anesthesia.

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The "Balanced Procedure" for the Treatment of Hiatal Hernia Complex

A Reaffirmation

*Jacob K. Berman, M.D.**

Vomiting, pyrosis, regurgitation, rumination, and substernal discomfort have been studied for centuries; and these symptoms were and are attributed to many divergent causes, real and imaginary. Conceivably, the word hypochondriasis was used at one time to describe patients with pain beneath the sternal cartilage – many of whom probably had regurgitation esophagitis.

In 1813, Magendie[19] made a significant observation on the process of vomiting. He removed the stomach of an experimental animal and substituted a pig's bladder. Apomorphine caused the animal to vomit, and Magendie concluded that vomiting was due entirely to muscular contractions of the abdominal wall. We now know that Magendie was only partially correct. The vomiting center is necessary for the act and it is impossible for the experimental animal to vomit if the center has been ablated.

But the induction of vomiting and regurgitation (which may initiate hiatal hernia) is an intricate mechanism dependent upon efferent fibers in the phrenics, vagi, sympathetics and spinal nerves to the abdominal muscles; also, cranial nerves to the muscles of the pharynx, palate, etc. The afferent impulses reach the center along many diverse routes, chiefly through the vagal and sympathetic fibers of the stomach and abdominal viscera. So vagal stimuli play an important role and may arise from reflex impulses arising in the stomach or some other part of the body; impulses received from the cerebral centers; and metabolites carried to the vomiting center through the blood stream. Moreover, pylorospasm is frequently associated with hiatal hernia complex.[1-14] Now, Keet and Heydenrych have made a statistical analysis of the occurrence of hiatal hernia and pylorospasm and have found this combination present in 16.5 per cent of their patients. They have also shown the effect of vagus stimulation, just above the gastroesophageal juncture, in dogs

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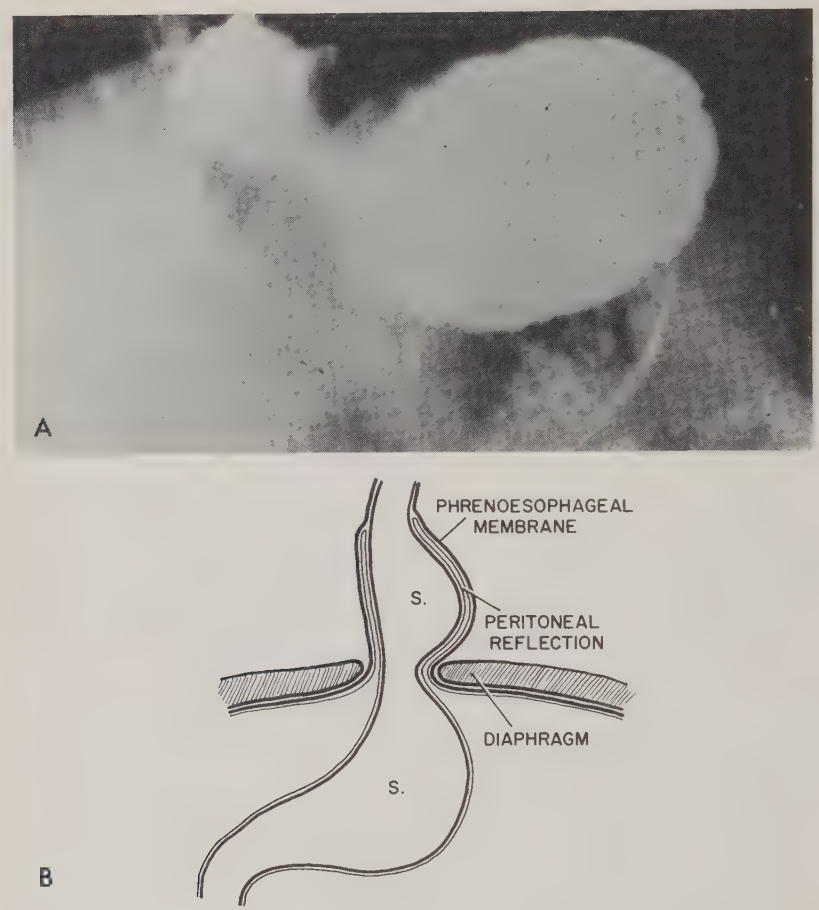


Figure 1. Hiatal hernia of the sliding (short) (brachyesophageal) type (90 per cent). There is a cephalad displacement of the cardia and loss of the esophagogastric angle. *A*, X-ray photo of barium swallow. *B*, Diagram illustrating the abnormality.

with hiatal hernia. This produced pyloric contraction, but the rest of the stomach remained flaccid. They call this the "hiatal-pyloric reflex."

So the problem of continued regurgitation and esophagitis is complex and not simply due to a cephalad displacement of the cardia. These observations led us to use a balanced procedure (Fig. 14) for the correction of hiatal hernia with its associated abnormalities and dysfunctions. Our first paper was published 13 years ago.[1] Now, we have performed the operation in over 650 patients. Most of these have been followed from 1 to 20 years. To this large number must be added many more treated by others[15, 16, 18, 20, 21, 22, 23] along similar lines. The results have been very satisfactory as the growing acceptance of our thesis indicates. Still, too often, sight is lost of certain fundamentals.

The purpose of this paper is to reaffirm our concepts of "the fundamentals" and to substantiate further the validity of our approach that

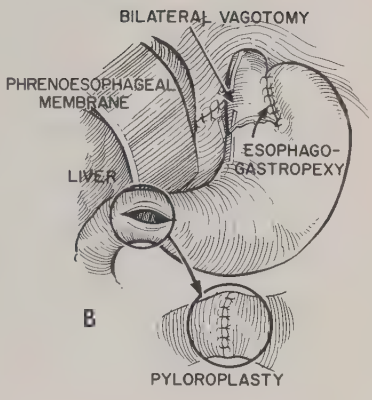
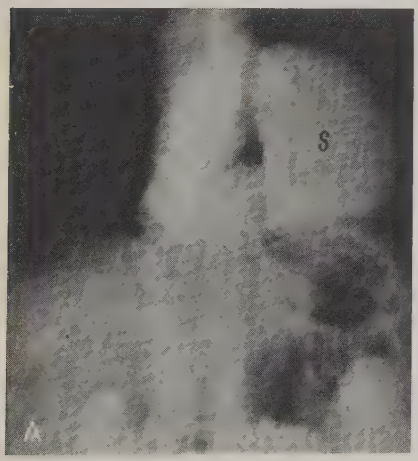


Figure 2. *A*, X-ray photo after balanced procedure. Same patient as shown in Figure 1. *B*, Diagram showing steps in the completed operation.



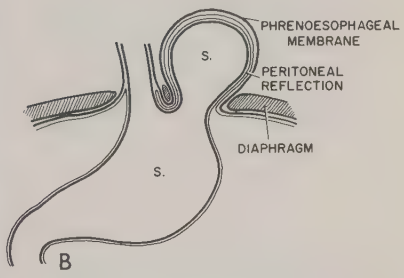


Figure 3. *A*, X-ray photo showing para-hiatal, paraesophageal, or (rolling) variety of hiatal hernia (3 per cent). *B*, Diagram illustrating the aberration. The esophagogastric angle is below the diaphragm "S", and though not acute, it is preserved. "S" shows fundus only above the diaphragm. This interferes with the physiologic sphincteric mechanism, which would close off the esophagus and prevent regurgitation. Predominating symptoms are substernal pain, dysphagia, and occult bleeding.

rests upon this thesis: *Hiatal hernia in itself is a very common anatomical abnormality, rarely significant unless either monstrous in size or associated with physiologic and other anatomic derangements.*[1-7, 8, 11, 12]

The associated derangements cannot be ignored, as the hernia is but a single factor in a complex problem. Therefore, unless the hernia is of the monstrous variety, *reduction alone carries an unnecessary risk of therapeutic failure.*

SYMPTOMS AND VARIETIES OF HIATAL HERNIA

Figures 1 through 6 and 8 depict the various types of hiatal hernia that have required surgical repair, and the techniques employed. It should be emphasized that the variety of hiatal hernia is unimportant so long as it is asymptomatic, or as long as symptoms may be easily controlled by medical management. It is seen that most hiatal hernias are of the sliding type (cephalad displacement of the gastric cardia through the esophageal hiatus). In every case requiring operation, medical management has been unsuccessful and the patient has presented with symptoms of peptic esophagitis (e.g., epigastric, substernal, or anginoid pain, "heartburn" or regurgitation) or symptoms *from* peptic esophagitis (e.g., cough from regurgitation and aspiration; or weakness from occult bleeding). A small but significant number of patients develop peptic esophagitis without hiatal hernia (Fig. 10) and yet they require the "balanced procedure." And some have severe esophageal spasm without definite evidence of regurgitation esophagitis. They too benefit from the balanced procedures (Fig. 11).

Patients, then, with hiatal hernia may have symptoms requiring surgical treatment, and patients without hiatal hernia may have the same symptoms requiring the same surgical treatment. Moreover, as our illustrations show, the hiatal hernia may vary in type. Hiatal hernia, therefore, is not the sine qua non of regurgitation esophagitis, though it may be a contributing factor. It may even be a major contributing factor.

With hiatal hernia reduced to secondary importance, the question must be answered as to what are the predominant symptoms of peptic or regurgitation esophagitis and what are its causes.

PEPTIC OR REGURGITATION ESOPHAGITIS

Nonspecific inflammation of the esophagus, like its counterparts in the stomach and duodenum, has a morbid propensity for ulceration, scarring, stenosis, bleeding, and occasionally perforation. Patients who have the disease complain of bizarre symptoms which are often mistaken for whimsical or capricious behavior rather than organic disease. Physical findings may be covert and their interpretation difficult. Treatment is often symptomatic, thus enhancing the risk of complications and failure to cure.

The relationship between function and inflammatory diseases is ob-

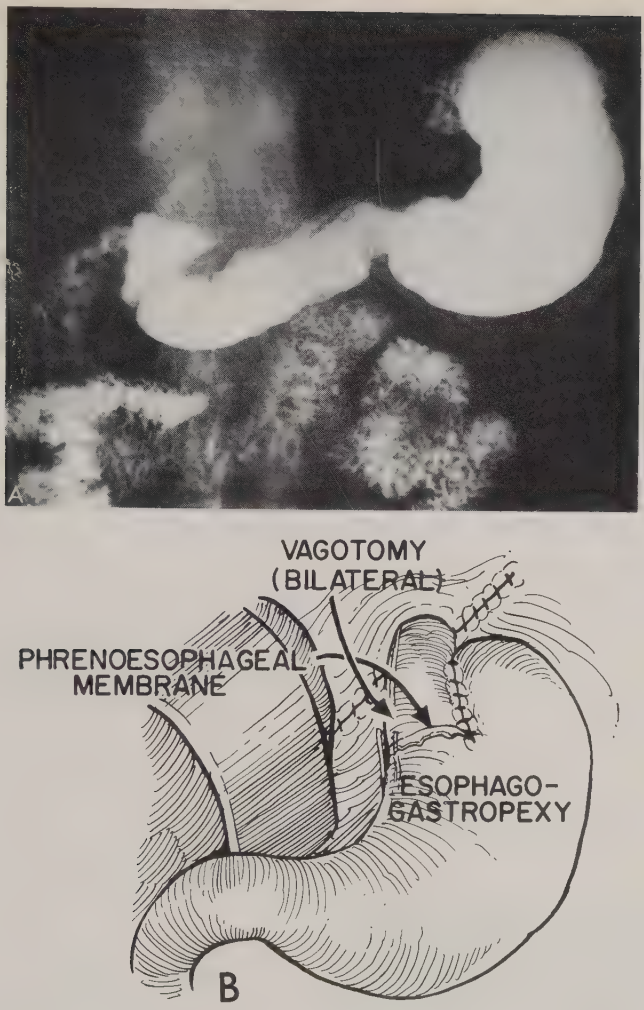


Figure 4. Same patient as in Figure 3, showing (*A*) the postoperative film with barium swallow and (*B*) the method of repair. Note that sutures in the hiatus have been placed posteromedially and anterolaterally, to keep the esophageal orifice in its normal position a little forward, to the left, and downward. The film was made 5 years after repair.

scure and its concepts abstruse. Theories concerning the cause of autodigestion involve the contributory action of pepsin and hydrochloric acid or alkaline digestive juices, as opposed to the inbred resistance of the mucous membrane or its impairment. The role which psychosomatic factors may play in initiating the disease is debatable, but the concept rests on more than tacit implication. This is evidenced by the general behavior of these patients, which is not one of equanimity but rather resembles the deportment of those who are said to have an "ulcer diathesis."[13]

Until more proximate or imminent causes are found for the condi-

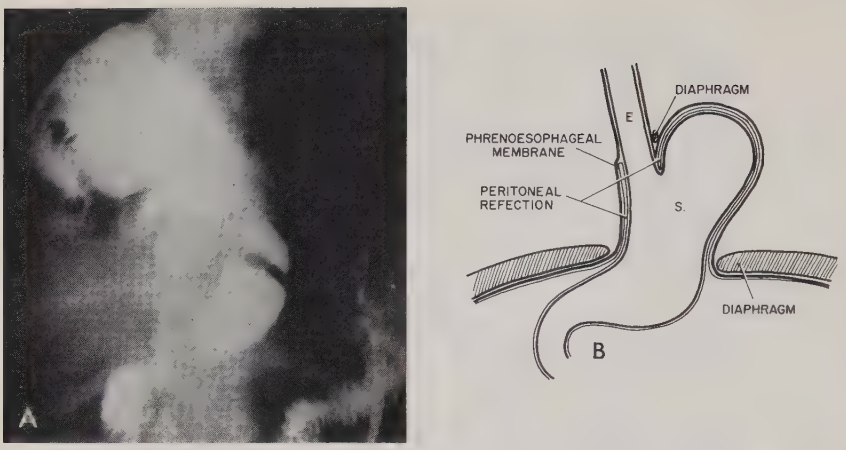


Figure 5. *A*, Hiatal hernia "en masse;" combination of sliding and paraesophageal hernia (6 per cent). X-ray photo. *B*, Diagram illustrating the defect. Note that the esophagus and fundus as well as the cardia move up, owing to the attenuation of some diaphragmatic filaments which persist. The physiologic sphincter cannot function properly. Dominant complaints: constant boring, bursting substernal pain radiating to the back.

tion, it is better to describe inflammation of the esophagus as regurgitation esophagitis rather than by the more specious term "peptic." Regurgitation better describes the condition because practically all of these patients regurgitate food or liquid (pyrosis) or chyme either completely into the oral cavity or partially for a variable distance into the esophagus. However, only about one patient in four who shows esophageal regurgitation fluoroscopically has esophagitis.

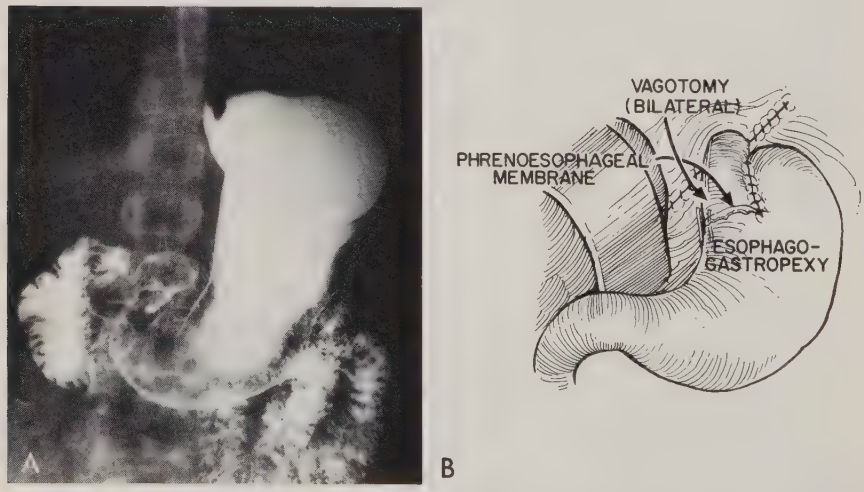


Figure 6. *A*, Barium swallow showing the postoperative result. *B*, Diagram illustrating the method of repair. Crura sutured posteromedially as well as anterolaterally to keep esophagus in normal position.

It must be assumed, then, that the esophagus becomes inflamed primarily because of the unremitting presence of digestive juices, either acid or alkaline, as opposed to the inbred resistance of the esophageal mucous membrane or its impairment, with subsequent mucosal irritation. This may be expressed succinctly as an equation of *physiologic factors* as follows: resistance, digestive juices, and time.

$$\frac{D + T}{R} = I$$

where *D* is the digestive juice, *T* is time or continuity, *R* is resistance of the mucosa, and *I* is inflammation.

Although less important, the *anatomic components* must also be considered. These and other anatomic factors may be added to the numerator of the equation as follows:

$$\frac{D + T + (a + b + c + d)}{R} = I$$

where *a*= hiatal hernia with cephalad displacement of the cardia, *b* = a loss or derangement of the esophagogastric angle, *c* = a dilated esophageal hiatus, *d* = a tight pylorus due to stenosis or spasm contributing to the avid retrograde gushing of food and juices.

ASSOCIATED LESIONS

A discussion of esophagitis would be incomplete without mentioning some of the associated lesions which are found with vexatious frequency. Many of the abnormalities may cause symptoms which mimic those of esophagitis. In a series of over 650 surgical cases of symptomatic hiatal hernia, the gallbladder was diseased in 30 per cent, the duodenum in 40 per cent, and the stomach in 10 per cent. This does not include derangements of the esophagus itself, such as diverticulum, stenosis (and its possible sequelae mega- and dolichoesophagus), cardiospasm, achalasia, and ulceration (Fig. 15). Thus, a true explanation for the protean manifestations of this disorder and its mordant effects is still inchoate.

SYMPTOMS

Patients with regurgitation esophagitis may complain of symptoms varying from mild eructative disturbances to persistent, often projectile vomiting; and from vague substernal unprecise pressure to progressive, disabling, severe pain radiating through to the back and both shoulders. Also, their ability to swallow may vary from short periods of cardiospasm to testy dysphagia. We have all listened to the petulant patients who describe with prolixity their complaints of dysphagia, nausea, epigastric, substernal or anginoid pain, "heartburn," regurgitation or vomiting,

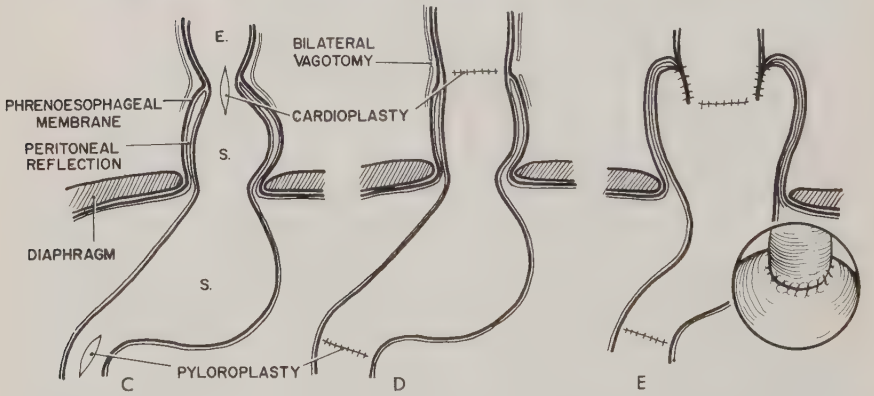


Figure 7. *A* and *B*, Barium swallow showing the long stricture in a patient with scleroderma (visceral sclerosis). *S*, stomach. *C*, *D*, and *E* illustrate the methods used in correcting this defect, consisting of cardioplasty, bilateral vagotomy, intussusception of the esophagus into the stomach and pyloroplasty.

pyrosis, and weakness (from occult bleeding). But the more cryptic symptoms due to esophagitis are those of productive cough and dyspnea (from aspiration pneumonitis); inability to bend or strain without regurgitation; or to lie down without eructations even with 2 or 3 pillows. The ordinarily abstemious patient may become intemperate and unrestrained because he is impelled by epigastric discomfort and a gnawing sensation to swallow something constantly. Milk, cream, and copious amounts of

antacids relieve pain temporarily. Many times, his symptoms are so similar to those of coronary disease that the clinical picture is indeed one of cardiac infarction, and even the electrocardiogram may show minor changes.

DIAGNOSIS

Usually, the physician will make the diagnosis after fluoroscopic or x-ray examination. But he will also resort to esophagoscopy. However, it should be emphasized that the size of a hiatal hernia, the amount of regurgitation under fluoroscopic examination, or the degree of acidity as measured in the regurgitant fluid have very little to do with the severity of symptoms. In fact, alkaline juices may produce esophagitis as well as those which are acid. Finally, the roentgenologist must be instructed to look for regurgitation esophagitis; this he will do by the Valsalva maneuver, the Trendelenburg, oblique, and prone positions; and by instructing the patient to sip barium through a tube with a side arm hole. Cineradiography is invaluable and helps in decisions regarding surgery.

TREATMENT

When we first treated esophagitis surgically, we simply tried to correct the factors which we thought were responsible; i.e., the physiologic

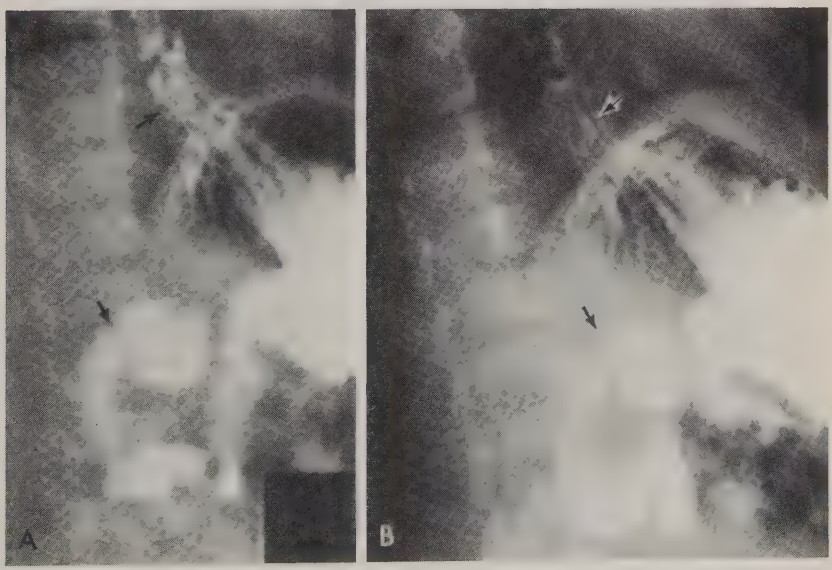


Figure 8. Thirteen month old male infant. Congenitally short esophagus and associated lesions. Chalasia since birth. Hemoglobin was 4 gm. on admission to the hospital. The child was unable to swallow without regurgitation. *A*, Oblique film of barium swallow showing hiatal hernia ↗ and duodenal ulcer ↘. *B*, Slightly different oblique view showing esophagitis with shallow esophageal ulcer ↙, also, duodenal ulcer with pylorospasms ↘. Balanced procedure performed with excellent results – no bleeding and no symptoms 9 years after surgery.

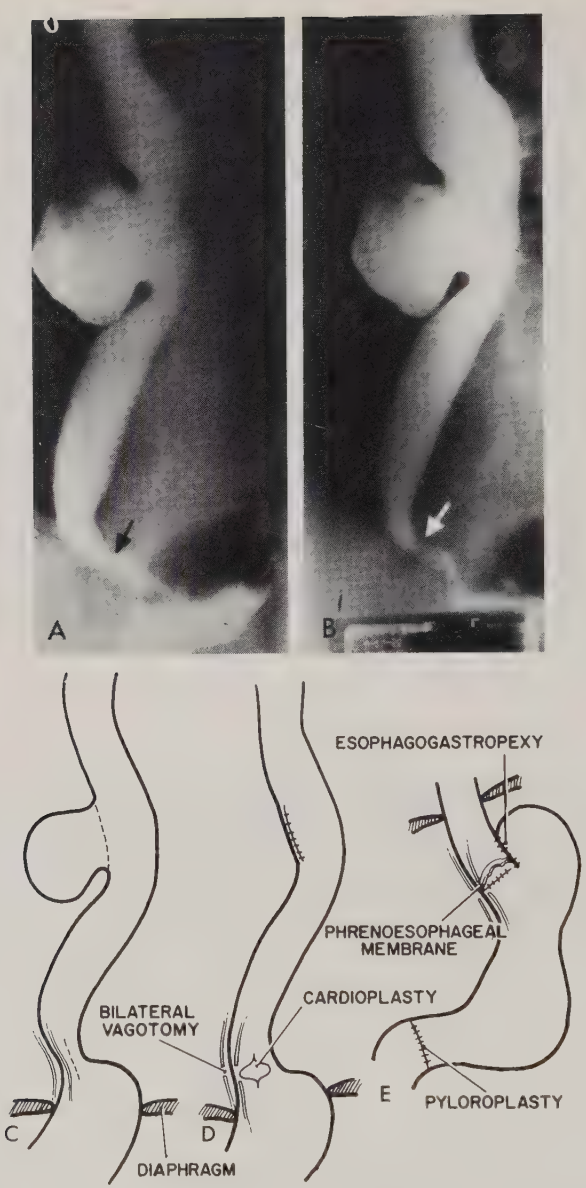


Figure 9. A 53 year old woman with a 10 year history of regurgitation, pyrosis, and substernal pain. In 1953 cholecystectomy and common bile duct exploration were carried out. Barium swallow shows a large mid-esophageal diverticulum. Esophagoscopy disclosed a large diverticulum 30 to 32 cm. from the alveolar ridge, associated with esophagitis, cicatricial stenosis, and sliding type of hiatal hernia. In 1958 a thoracoabdominal diverticulectomy and balanced procedure were done. *A* shows the large esophageal diverticulum. The arrow points to the stenosis at the esophagogastric juncture. *B*, Another view showing cicatricial stenosis at the esophagogastric juncture. *C*, Method of repair. Diverticulectomy and vagotomy, thoracic approach. *D*, Cardioplasty (Heineke-Mikulicz technique). *E*, Balanced procedure with pyloroplasty. Patient had no recurrence of symptoms 6 years later, and is now lost to follow-up. This illustrates the necessity of correcting not only the diverticulum, but what appears to be a causative factor—the hiatal hernia and esophagitis with cicatricial stenosis.

Figure 10. Barium swallow showing a patient with esophageal regurgitation, without hiatal hernia. There is a loss of the esophagogastric angle and esophagitis – the regurgitation was clearly shown up to the mid-esophagus.

and anatomic factors as previously enumerated in the equation. This, of course, is empiricism in every sense of the word. But patients who were operated upon had endeavored for years to obtain relief from variegated medical treatment and usually from a multitude of different physicians. For the most part, the physician was aware of the fact that the patient did indeed have a "small sliding hiatal hernia of little consequence or a Schatzki ring or Ingelfinger band." But he may not have been aware of the fact that size is often unrelated to symptoms and that no hiatus hernia may be demonstrable by ordinary fluoroscopy, yet the disease may be found to be advanced on endoscopic examination. Moreover, spasm of the esophagus may occur with or without reflux, hiatal hernia, or esophagitis (Fig. 11). Studies have shown that only about one fourth of hiatal hernia patients need surgery for the control of symptoms.

About 20 years ago, Dr. E. J. Berman and I began using a procedure to remedy the more probable factors in the causation of this complex disease. Since most patients with regurgitation esophagitis had a sliding type of hiatal hernia, a "balanced procedure" (for lack of a better term), was designed to correct the many aberrations which might be present in

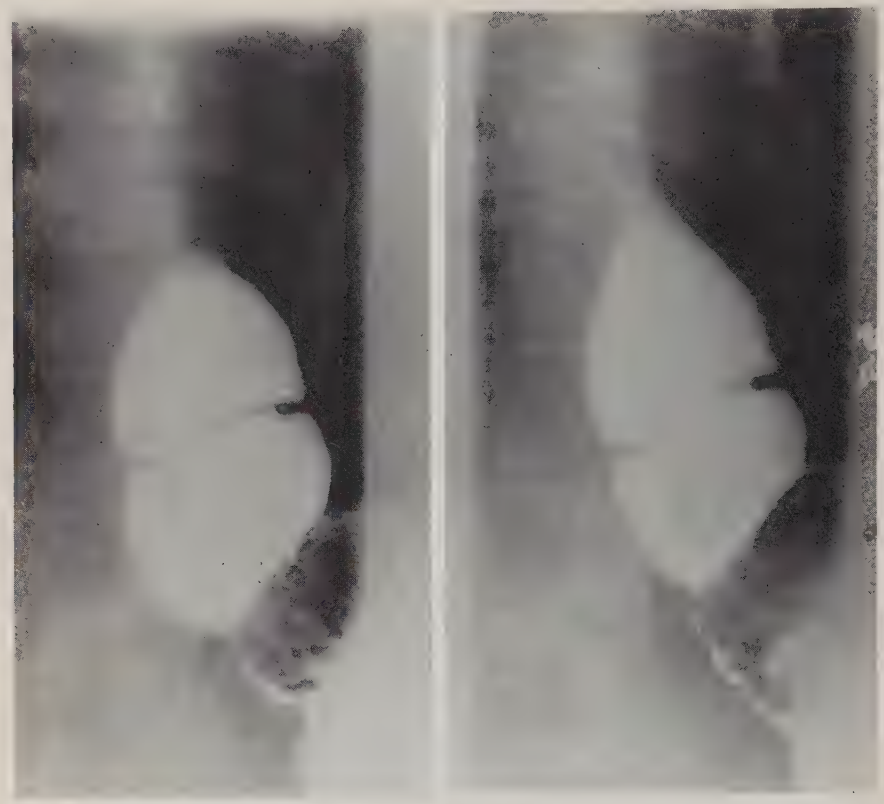


Figure 11. Hiatal hernia without evidence of esophagitis showing spasm (Schatzki ring). Symptoms were episodic epigastric pain. Medical management controlled symptoms. Surgery was not performed.

this multifaceted problem. It is apparent that an operation to correct regurgitation esophagitis must be balanced to give due consideration to each of the disease components, both *physiologic* and *anatomic*. It is this concept which should lead the thoughtful surgeon to employ routinely five steps in the operative procedure. Since it is usually impossible to delineate the factors of the equation producing the greatest difficulty, the *basic procedure* should include the following maneuvers:

1. *Reduction of the hiatal hernia to correct the displacement of the cardia.* It is necessary to have the esophagogastric angle well within the abdomen free and untethered so that the physiologic cardiac sphincter may perform properly. Sphincteric action may be due chiefly to the increased abdominal or fundic pressure (as compared with the sub-atmospheric pressure in the chest).

2. *Bilateral truncal vagotomy* to lessen the quantity and therefore the continuity of large volumes of digestive juices. Also, it facilitates the descent of the esophagus. In addition, 28 per cent of our patients had a gastric or duodenal ulcer or duodenal scars. Twelve per cent were shown

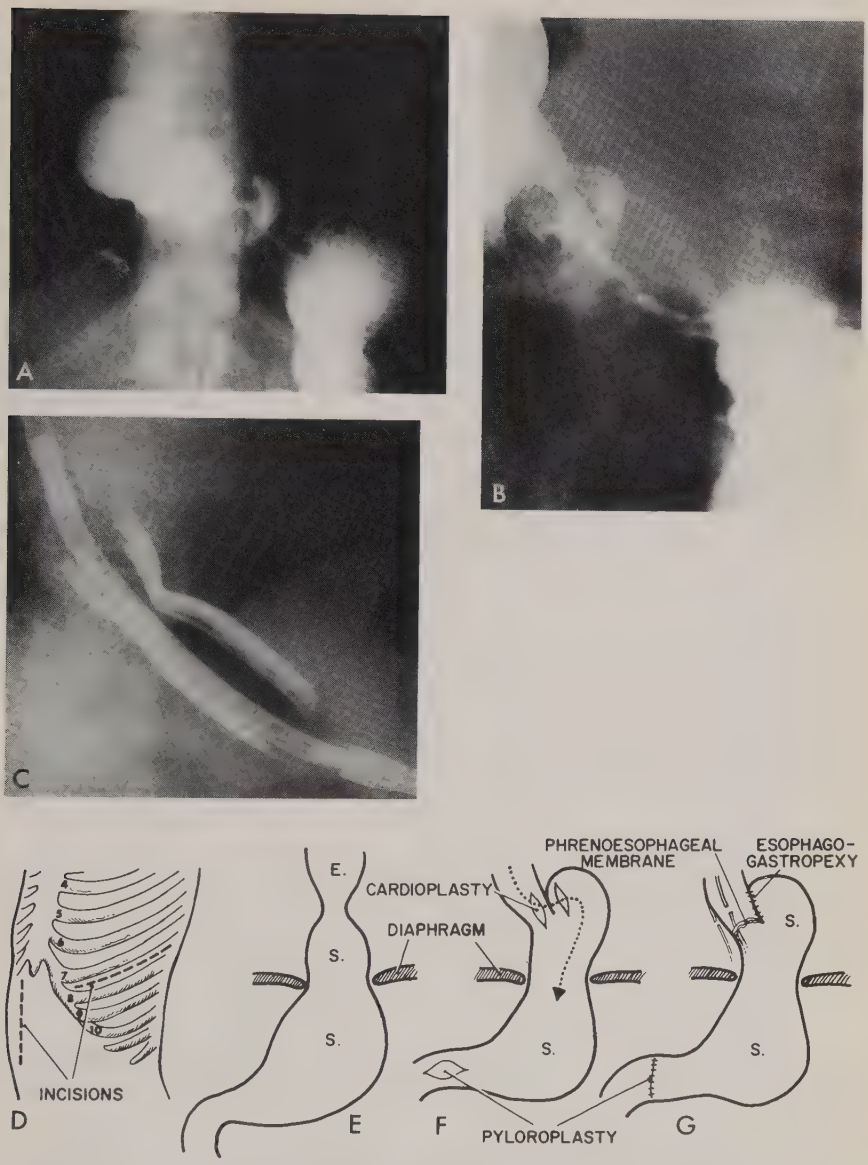


Figure 12. A 56 year old man with symptoms of hiatal hernia complex beginning in 1941.. Medical management and esophageal dilations were done over 18 years. In 1959 a cardiomyotomy (Heller) was done elsewhere. He experienced relief for 14 months, then had repeated esophageal dilatations. In 1961 a balanced procedure with cardioplasty and esophagoplasty (thoracoabdominal approach) was carried out. *A*, Preoperative x-ray films showing mega and dolicho-esophagus with hiatal hernia and esophageal stenosis. *B*, X-ray photo showing advanced cicatricial stenosis. *C*, Postoperative film showing Mosher bag in place with 8 pounds of pressure. Note the esophageal narrowing—the patient has required further dilations. *D*, Thoracoabdominal approach. Confluent cartilages of the seventh through the tenth ribs are preserved. Incision in eighth intercostal space. Right paramedian abdominal incision. *E*, Diagram showing the abnormality. "E," esophagus; "S," stomach. *F*, Esophagogastrostomy, esophagogastropexy, and truncal vagotomy. *G*, The completed operation with pyloroplasty.

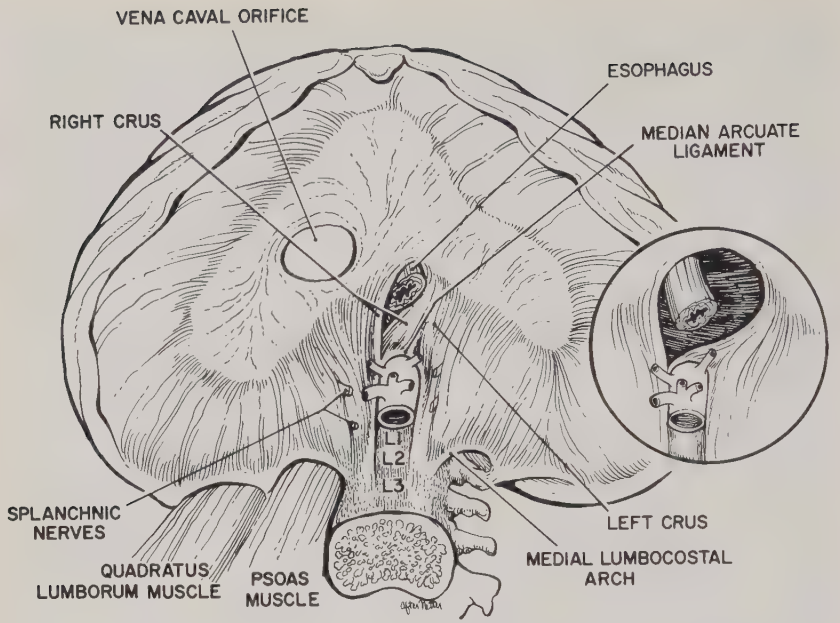


Figure 13. Diagram illustrating the anatomy as seen from below the diaphragm in the correction of hiatal hernia. Note that the right crus takes origin from the anterior surface of the bodies of L1, 2 and 3, whereas the left crus arises from L1 and 2. It is usually the right crus that splits to encircle the esophagus. Both crura then join the central tendon of the diaphragm. The medial part of each crus is wholly tendinous and is connected with its fellow of the opposite side by a tendinous band called the middle arcuate ligament. The crura at the sides and behind form a flat surface, not an edge, toward the esophageal orifice. The plane is oblique.

to have a nonspecific duodenitis (proved by microscopic examination on our wedge resection of the pylorus).

3. *Repair of the enlarged hiatus* to decrease its size so that it fits snugly around the esophagus (see Fig. 13). This will help insure a permanent reduction of the cardiac end of the stomach to its normal position.

4. *Esophagogastropexy.* This term is used to describe a re-creation of the esophagogastric angle (angle of His or plica cardiaca) and the formation of a shoulder to help prevent recurrence. The gastric fundus is sutured to the lower remnant of the phrenoesophageal membrane and the lateral side of the esophagus.

5. *Pyloroplasty* (modified Heineke-Mikulicz), with a wedge resection of the pylorus, makes possible the digital exploration of the interior of the duodenum and the stomach. The gastric outlet is enlarged so that ingested food may find egress without delay. The wedge of pylorus permits microscopic examination.

EXPANDED SURGICAL PROCEDURE

In addition to this basic operation, an attempt is made to correct associated diseases wherever possible. It would, for example, be as ingenu-

ous to leave a hiatal hernia at the time of a cholecystectomy as it would be to do the reverse. Also, it would be unwise to repair an esophageal diverticulum without relieving a stenosis below it, or correcting the hiatal hernia causing the stenosis (Fig. 9). Hiatal hernia in itself is not the sine qua non of esophagitis, and the patient may need only vagotomy, esophagogastropexy, and pyloroplasty to cure his symptoms.[24] Sometimes it is necessary to use a transthoracic approach (for esophageal stenosis, diverticula, congenitally short esophagus, or neoplasm) and occasionally a combined abdominal and thoracic operation must be employed (Fig. 12).

The important consideration is that once esophagitis is present and cannot be adequately controlled by medical management, surgery is indicated, because the disease is usually progressive.

LARGE OR MONSTROUS HERNIA

When hiatal hernia is of enormous size, long-standing distress can come from the displaced stomach without the presence of esophagitis.

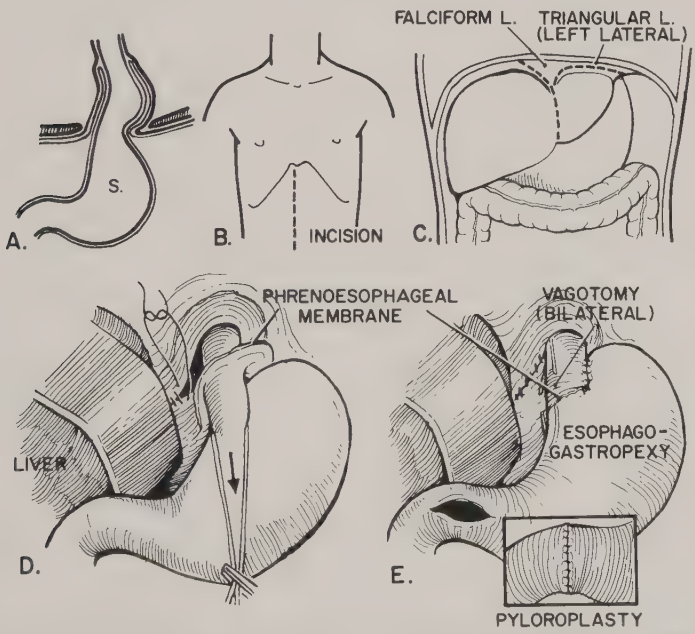


Figure 14. Balanced operation for esophageal hiatal hernia complex. *A*, Sliding or so-called acquired short esophageal hiatal hernia showing cephalad displacement of the cardia and loss of the esophageal gastric angle. S, stomach. *B*, Right paramedian incision. *C*, Mobilization of the liver by division of the left triangular (left lateral) and falciform ligaments. *D*, Bilateral truncal vagotomy allowing complete reduction of hernia and descent of the esophagus, also illustrating the repair of the crus posteromedially. Note that the divided phrenoesophageal membrane at its lowermost attachment is used in the esophagogastropexy. *E*, The completed operation with restoration of the esophagogastric angle by esophagogastropexy. Pyloroplasty is performed to facilitate emptying. Associated lesions are corrected. The phrenoesophageal membrane cannot be identified as an individual structure. As here depicted in our diagram, it is composed of posterior peritoneum with a few decussating fibers from the crura. It is difficult, if not impossible, to demonstrate any direct connection between the esophageal muscular fibers and those of the diaphragm.

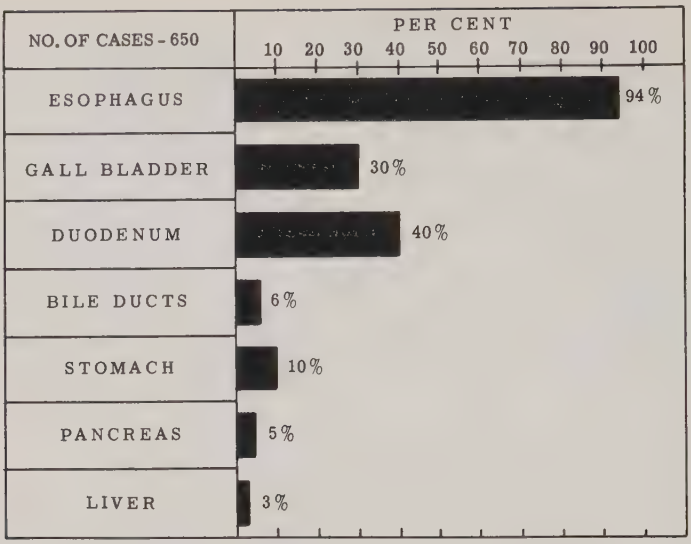


Figure 15. Significant associated lesions in hiatal hernia complex. Note that the incidence of gall bladder disease is 30 per cent, whereas the duodenum is involved in 40 per cent. The reason this was placed in the third column was because many of our wedge resections showed duodenitis without specific ulceration. If a specific ulcer or scar was encountered, the percentage would be roughly 28 per cent. The same variation is noted under "stomach," which is 10 per cent if microscopic evidence of gastritis was present. For a stomach ulcer, the figure would be roughly 3 per cent. Liver diseases encountered include nutritional, post necrotic or cholangeolitic cirrhosis, also granuloma and hemangioma.

Pain is the predominant symptom – it is described as boring and bursting, and radiates through to the back. Anatomic consideration here far outweighs the physiologic. Further, it is here that we encountered one of our very few cases of bona fide congenital short esophagus where esophagogastroplasty (to relieve stricture) without reduction of the hernia was all that was possible. We had attempted repair in this case from below the diaphragm and had only been able to perform pyloroplasty.[8, 25]

We use the thoracic approach occasionally in very old people who are obese and have long-standing monstrous hiatal hernias.

Esophageal Spasm or Stricture

In most cases, the balanced procedure alone corrects esophageal spasm or what appears to be a stricture. Postoperative dilation is rarely required and will be rarer still if the hiatus is not repaired too tightly. An anastomotic procedure in the area of the cardia has been required only twice thus far. In these instances, a Heller type cardiomyotomy would not suffice to enlarge the lumen. Thus, the Heller procedure has not been used (Figs. 6 and 12).

Postoperative Complications

Postoperative complications are listed in Table 1. Most of the difficulties have been transient and easily controlled without further operative procedures. When we first performed the balanced procedure, we made the hiatus too tight. Three of this group required esophageal dilations.

Table 1. *Significant Postoperative Complications in 650 Patients Having Balanced Operations for Esophageal Hiatus Hernia Complex*

COMPLICATION	NO.	PER CENT	RESULT
Immediate postoperative distention	65	10	Transient; treated with d-pentothenyl alcohol (Ilopan)*
Diarrhea	26	4	Controlled with Normacid, Lomotil and Siblin; 3 patients still have 3 to 4 stools; 2 patients with gastric resection have 5 to 6 stools
Wound infections:			
Superficial, in incision; no recurrence of hiatal hernia	10	1.5	Healed by second intention without complications
Deep infection; recurrence with symptoms	2	.3	Reoperation refused
Transient substernal pain without demonstrable recurrence or esophagitis, probably due to overcorrection of hernia	6	.9	All relieved 3 to 6 months with one or more instrumental dilatations
Recurrence of hiatal hernia with symptoms	6	.9	Reoperation with good results in 2; reoperation refused in 2; one of these listed under "wound infection", 2 reoperation transthoracically
"Dumping syndrome"	6	.9	Relieved by frequent feedings, sham feedings, antihistamines, except in 2
Hepatic insufficiency in nutritional, postnecrotic, and cholangeolitic cirrhosis of liver	4	.6	Two died; 2 recovered
Recurrence of stenosis in cases of megaesophagus and dolichoesophagus	4	.6	Treated with dilatations for about 6 months; now free of symptoms, but dilatations continue periodically; 1 required esophagogastrostomy
Incisional hernia, 1 and 2 years after operation	3	.4	Repair with recovery
Coronary occlusions	2	.3	Death
Acute gastric dilatation	3	.4	Two transient required nasogastric tube and dexapanthenol, 1 required posterior gastrojejunostomy
Spontaneous pneumothorax and empyema	1	.15	Under water-seal drainage. Died of cerebral embolus

*Drugs: dexapanthenol (Ilopan); betaine hydrochloride 440 mg., pepsin, 32 mg. dilution 1:10,000 (Normacid) dephenoxylate hydrochloride and atropine sulfate (Lomotil).

RESULTS

Our experience and that of others (see references) has shown that 94 to 95 per cent of patients have had a good to excellent result. The rationale of our balanced procedure is based on the fact that we do not know which of our steps are necessary to produce good results before operation and the same is true at the time of surgery.

SUMMARY

Hiatal hernia in itself is a common anatomic abnormality, rarely significant unless either monstrous in size or associated with physiologic and other anatomic derangements. Unless the hernia is of enormous size, it is essential to approach the problem as one of regurgitation esophagitis. Significant associated lesions are common and must be searched for. The phrase "hiatal hernia complex" is used to avoid emphasis on any one part of a multifaceted problem. The need for flexibility in the surgical procedure applied to the hiatal hernia complex is apparent.

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Use of Wire Mesh Prostheses in the Treatment of Hernia

24 Years' Experience

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In 1958 a 9 year personal experience with steel cloth implant repair of 951 hernias was published as a preliminary report.[2] The current report, using the same procedure in more than 2000 patients over a 24 year period, confirms the conclusions of the preliminary report.

The purpose of this article is to present our personal experience with the use of annealed stainless steel mesh and to present methods for improving the results of hernioplasties, describing techniques used and presenting technical details in the use of annealed stainless steel sutures.

Nearly all hernias can be repaired in some manner without the use of a prosthesis. The recurrence rate can be reduced, however, by using a suitable prosthesis repair in appropriate cases. Hernia tends to develop in a person who has a congenital abdominal wall weakness or who has acquired incompetence of abdominal wall tissues. If these weakened tissues, which have already failed to retain the abdominal contents, are the only supportive structures relied on for repair, then an unacceptable rate of recurrence can be anticipated. Use of steel cloth prostheses for repair is justified by clear evidence of reduction in the recurrence rate which can be obtained with it. Standard methods have their value but should not be used to the exclusion of other methods which are now known to offer a better prognosis for cure in selected cases.

McVay emphasizes the importance of the strength of the posterior wall of the inguinal canal in the repair of indirect hernias. If a strong canal floor is not obtained, the patient often returns several years later with a direct hernia. McVay[1] postulates that such circumstances could be avoided by reconstructing a new posterior inguinal wall in every case of indirect inguinal hernia. Steel cloth implant repair is an acceptable, posi-

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tive, reliable approach to strengthening the posterior wall of the inguinal canal without subjecting the patient to a lengthy, less certain repair with the patient's tissues.

Others have reported the morbidity and mortality rates associated with hernias and their repair. Hernias are also responsible for considerable economic loss to the patient, the family, and the nation. It is, therefore, important to perform the type of operation which will offer the best chance for a permanent cure with minimal risk.

McVay[1] has clearly established the principles of inguinal hernia repair: (1) proper ligation of the sac, (2) correct evaluation of the posterior inguinal canal, (3) recognition of a femoral hernia, (4) proper closure of the internal ring, (5) recognizing damage to the posterior wall. The only type of recurrent hernia to be anticipated is in the direct area. For this reason, steel mesh implant repair, to build a secure posterior wall of the canal, is justified in most cases. Infants, children, and adolescents have shown a high rate of cure from standard procedures and do not require implant repair.

Successful repair of all types of hernias in patients whose musculature is of poor quality requires something more than the material supplied by the patient. This is apparent from the frequency with which one finds attenuated transversalis fibers, weak flabby muscles, and thin fascial coverings. Attempts to build a firm posterior wall with such weak structures frequently fail.

There are certain conditions which present a relatively high risk of recurrence, unless special methods are employed. These include patients with a chronic cough, increased intra-abdominal tension from obesity, recurrent hernias, large ventral or epigastric hernias, incisional hernias, and direct inguinal hernias. A gratifying reduction in recurrence rate in these patients can be obtained by steel cloth prosthesis repair. Any improvement in a patient's condition, such as weight reduction, increase of muscle tone, and cessation of smoking, will further reduce the number of recurrences. Unfortunately, very few are willing to forego these dubious pleasures.

Selection of the most suitable material for the prosthesis implies that it will be inert in tissue and have lasting strength. Contrary to the belief of some, fibrous tissue and scar tissue are weaker than normal tissue and thus contribute to recurrence of hernia. Personal experience with injections of sclerosing solutions to produce scar-tissue repair of hernias, the use of fascia lata strips, cutis grafts, or implanted tantalum mesh, glass cloth, or Marlex mesh have been disappointing because of damaging tissue reactions, fragmentation in tissues (tantalum), and an unacceptable recurrence rate.

Though a careless surgeon will have poor results by any method and a good surgeon may have good results with poor methods, optimum success in the hernioplasties is obtained by observance of certain sound surgical principles. These include aseptic technique, avoidance of placing materials in the wound which will cause tissue irritation or excessive fibrous tissue formation, observance of strict hemostasis, avoidance of injury to nerves and blood vessels, gentleness in handling of tissues, avoidance of strangulating sutures, and maintenance of optimum local blood

supply. Proper placement of steel mesh is a complementary support to weak tissues, permits a secure closure without tension, supplies maximum strength and minimum irritation in the tissues, facilitates optimum blood supply at the site of repair, and does not injure nerves.

Large epigastric, incisional, and ventral hernias are a special problem when the musculofascial edges of the defect cannot be coapted by sutures or when such closure produces excessive wound tension. Excessive tension is the enemy of good healing because it impedes the local blood supply to the area where optimum blood supply is most desirable. A reliable and secure closure of these hernias can be provided with a blow-out patch of steel cloth (Fig. 1). Use of the prosthesis affords firm retention of abdominal contents without excessive wound tension. It is neither necessary nor advisable to coapt the musculofascial edges. Omentum should be interposed between the implant material and the intestine to prevent bowel from adhering to the prosthesis.

Selection of annealed stainless steel fabric as a suitable prosthesis was suggested by prior favorable experience with annealed stainless steel monofilament sutures and ligatures. This suture material was used long before mesh implant repair was considered. Annealed stainless steel has proven to be inert in living tissue, has permanent strength and durability, does not have a tendency to work-harden, and is malleable. The materials used for repair of the hernias reported in this series were monofilament 18–8 stainless steel 50-mesh ("Surgalloy") and monofilament 32 and 35 gauge 18–8 stainless steel sutures and ligatures. These can be obtained from surgical supply houses or, at much less cost, from various manufacturers of wire and wire cloth. Multifilament or braided steel sutures are not recommended because of their sawing action in tissues and tendency to fray.

A method for repair of inguinal hernia with a steel cloth implant is shown in Figures 2 and 3. The chief advantage of this blow-out patch repair over standard hernia operations is the greater security in closure which depends on firmly anchored steel cloth and not on weak or attenuated tissue layers sutured to each other. Distribution of intra-abdominal pressure over the extent of the implant is better retained than the same pressure applied to a narrow line of sutured tissue under tension. Intra-abdominal pressure is transmitted by the implant to its anchored position behind the pubic bone.

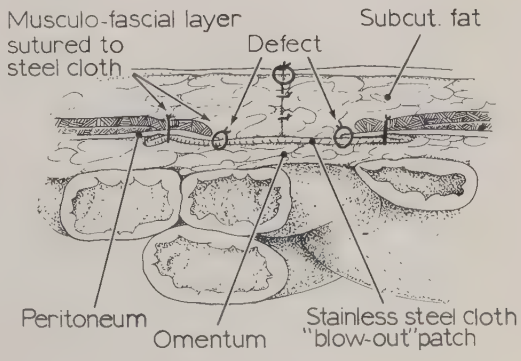

Figure 1. Reliable closure of abdominal wall defect made with steel cloth blow-out patch. Undesirable excessive wound tension is avoided by omitting coaptation of widely separated edges of musculofascial layer.

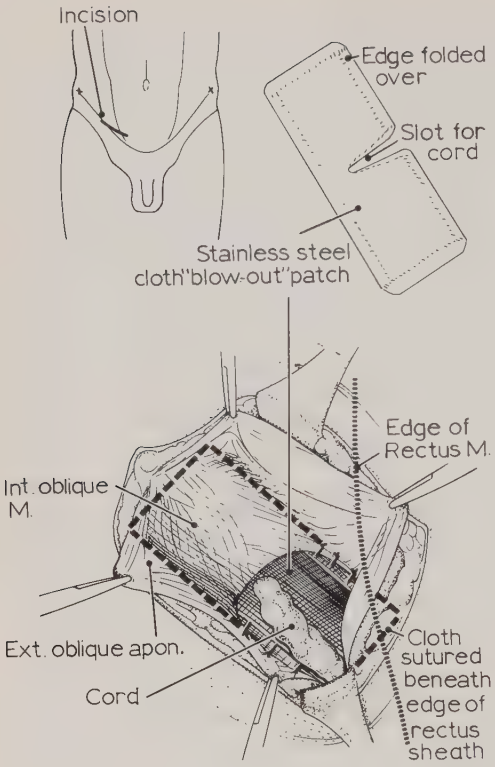

Figure 2. The implant is cut at the operating table to fit the area of abdominal wall weakness and slotted to accommodate the cord through its central portion. It is anchored medially under the conjoined tendon and edge of the rectus sheath, and laterally to Cooper's ligament and the shelving edge of the inguinal ligament with interrupted stainless steel sutures.

Two different methods of placement of the mesh have been employed in inguinal hernioplasties. The first has been direct application of the prosthesis to Hesselbach's area. The implant is cut to fit the defect and slotted to accommodate the cord. This is illustrated in Figure 2. It is anchored to the pubic tubercle and behind the pubis distally, to Cooper's ligament and the inguinal ligament laterally, and sutured under the conjoined tendon and beneath the edge of the rectus sheath medially. In order to prevent recurrences at the internal ring and just medial to it, the mesh is snugged around the cord. It is most important to securely suture the implant in a deep position at the pubic tubercle and behind the pubis to prevent recurrence in an area most often a site of weakness after an orthodox repair (Bassini, Halsted, Ferguson).

The second method (used by Richards) disregards the increased wound tension resulting from a McVay repair under the insertion of the implant. This is an on-lay patch. It affords double support in the area of the pubic tubercle and supplies a double barrier to a breakthrough in Hesselbach's area; however, we have found that on-lay patches are not as strong as an implant which is inserted under the conjoined tendon and attached under the edge of the rectus sheath. An on-lay prosthesis is much less reliable than implanting the steel mesh under the musculofascial edges, which gives the mechanical advantage of a blow-out patch. Richards now feels that application of the mesh to Hesselbach's area alone, without a Cooper's ligament repair, satisfies the criteria for the use

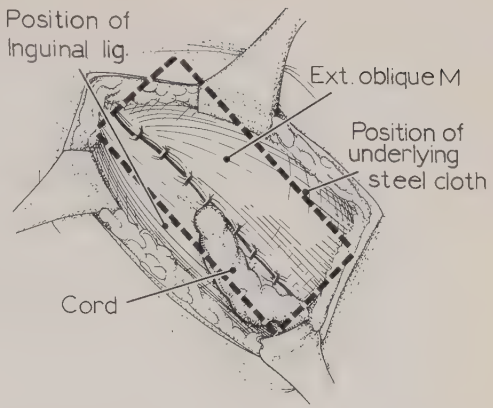

Figure 3. The edges of the external oblique aponeurosis are united with interrupted steel sutures over the implant and beneath the cord. Fibroblasts grow through the mesh of the implant, making it an integral part of the abdominal wall.

of a mesh prosthesis. There may be excessive wound tension even with a relaxing incision in the McVay repair, particularly at the area of the transitional sutures which can be avoided with blow-out patch repair. Furthermore, the technique of implanting the prosthesis is less time consuming, and it carries with it a minimum of postoperative pain and disability.

Marlex mesh or Merseline mesh has been advocated by some as soft fabrics for use in bridging defects or to place in direct or recurrent inguinal hernias. These are organic materials and are not as readily accepted by tissues as stainless steel. Wire mesh is not as pliable and soft, but it has two qualities, other than being inert in tissues, that are superior. First, it can be cut to fit the defect and, by folding the edges, one is afforded a strong area on the periphery through which to pass sutures. Marlex cannot be cut to fit a specific defect and still present an edge that will hold sutures well. Secondly, Merseline, silk, or similar sutures, to fix the plastic mesh, require multiple-throw knots and a 6 mm. "tail" to prevent slippage. More organic foreign material in the wound causes greater tissue reaction, and increases the risk of infection, draining sinuses, and other complications.

In the more than 2000 repairs that we have done, the incidence of infection is 0.1 per cent. In reviewing all our cases, we found none that had become infected primarily. Stainless steel mesh has been put in wounds that have been infected at the time of its insertion without the formation of sinus tracts or abscesses. The infected cases have been evisceration of abdominal wounds, or recurrent abdominal wall hernias following the use of tantalum where small bowel fistulas had developed. In no instance has it been necessary to remove a steel cloth implant because of wound drainage or infection. Prophylactic use of antibiotics is not recommended.

Stainless steel suture technique provides best results when fine sizes, 35 to 32 B and S gauge, are selected. The suture should not be excessively stronger than the structures being sutured. Coaptation of structures without strangulation is desirable. A square knot with the second loop of the knot securely seated produces a high coefficient of friction between the loops so that the suture ends can be cut flush with the knot without risk of it untying. Twisting the wire, cutting it, and turning the

ends over is not a satisfactory substitute for a square knot with ends cut flush and may cause postoperative tenderness and pain at the site of the sutures.

There is no advantage in using heavy wire (No. 30 or 28) as it does not provide any increase in wound security. A satisfactory technique for tying annealed steel wire is to use a hemostat and tie a simple square knot, the ends being cut flush with special wire scissors. It is difficult to cut wire with the usual suture scissors. The wire scissors we use are short, thin-bladed scissors with serrated edges. It is essential to tie a square knot with loops flat and not rotated to avoid possible slipping of the loops. The triple throw or "surgeon's knot" has no advantage over a square knot when annealed steel sutures are used. Wire sutures are best cut by the operator—not an assistant. It is necessary to put upward traction on the suture ends so the scissors can be placed right at the knot. This prevents protruding sharp ends. In any wound in which wire is properly tied with a square knot and cut flush, it is possible to run a gloved finger over the sutures and not catch a suture in the glove. Absence of protruding suture ends obviates complaints from patients of postoperative sticking or burning sensations. Some patients who have had improper wire suturing have required later removal of the sutures because of postoperative pain.

Judgment of the surgeon in selecting the appropriate method and technique for obtaining the best results is an important ingredient of all successful hernia operations. Each hernia is an individual problem and should not be subjected to a routine treatment. Steel cloth implant repair with steel sutures is an appropriate procedure for many hernias and may be considered as a routine in all inguinal hernias except in infants, children, and young adults. It is especially recommended for those defects which cannot be closed by suturing the musculofascial edges without causing excessive wound tension. Furthermore, if mesh were used in all inguinal hernioplasties, the number of second operations could be reduced to a minimum. In the healing process, fibroblasts grow through the steel mesh and make it an integral part of the abdominal wall. Steel mesh prosthesis repair is a rational procedure which favors prompt healing and a high rate of cure because it affords a secure closure without excessive tension. Tissue reaction is minimal and optimal local blood supply is maintained.

Wire mesh implants and steel sutures are not foolproof and do not guarantee perfect results, but when they are used with reasonable skill and judgment, it is believed that better results can be obtained with them in appropriate cases.

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The Problem of the Recurrent Inguinal Hernia

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Inguinal herniorrhaphy is one of the most common surgical procedures performed in the United States, and, although accurate statistics are not available, certainly thousands of herniorrhaphies are done annually. It is somewhat paradoxical that herniorrhaphy is frequently delegated to the youngest and most inexperienced house officer or surgical resident, despite the fact that even the most outstanding and senior surgeons do not agree on the anatomy of the inguinal region or the best type of hernia repair to be utilized. This becomes even more of a paradox when the "accepted" recurrence rate of primary herniorrhaphy in the adult is reported from 2 to 10 per cent, with several reports from England quoting rates approaching 20 per cent. The recurrence rate of a previously repaired inguinal hernia may be 20 per cent or higher. These rather appalling statistics suggest that the general surgeon should not only re-examine his own methods and concepts of inguinal herniorrhaphy, but impart his experience to the surgical resident staff, and not allow junior house officers to perform primary or recurrent herniorrhaphies without adequate supervision.

Terminology

The first step in analyzing any series of recurrent hernias is the definition of terms, because of the almost universal lack of agreement in this regard among investigators. Examiners may even differ as to what actually constitutes a recurrent hernia. Is a slight bulge or an inguinal impulse felt on coughing or straining a recurrent hernia, or must there be a definite mass present? Is there a minimum size requirement for the mass? Should a direct hernia developing in an adult many years after an indirect herniorrhaphy in childhood be classified as a recurrence or as a new hernia? It is probable that many "recurrent" hernias are not actually recurrences, but defects overlooked or missed at the time of the original

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operation. Finally, some hernias may be produced by the surgical procedure itself. Glassow points out that several of his patients developed a femoral hernia following the Shouldice repair of a direct inguinal hernia, although a prior careful intraoperative search for femoral hernia had been specifically carried out and documented.[2] Thus, any discussion of the problem of the recurrent hernia may be innately associated with confusion and disagreement.

Reasons for Recurrence

Several parameters should be discussed as factors contributing to recurrence of a hernia. Most authors agree that associated pulmonary disease is one of the greatest hazards in the proper postoperative healing of a herniorrhaphy. Therefore, patients with chronic pulmonary disease should be provided with a course of pulmonary physiotherapy several days before operation in an attempt to control their cough.

Wound infection is often mentioned as a significant factor in the development of a recurrent hernia. Certainly if a wound infection does occur, the probability of an early recurrence is increased. However, the incidence of wound infections severe enough to impair the integrity of the hernia repair is low enough to minimize this factor as a significant threat to the herniorrhaphy patient.

Duration of the hernia and age of the patient are certainly factors which may affect the successful outcome of the repair. It is reasonable to assume that a small hernia of recent onset in a young patient with strong tissue is more likely to heal favorably than a large, long-standing hernia in an older patient with attenuated, torn tissue.

Probably the most significant factor in the failure of a herniorrhaphy relates to the inadequacy of the primary operation. Errors in the choice of procedure, technical faults in its performance, and unnecessary trauma to the tissue forming the inguinal floor are all of great importance.

SURGICAL TECHNIQUES IN RECURRENT HERNIA

All surgeons agree that repair of a recurrent hernia carries a much higher incidence of further recurrence than does primary repair of a hernia. Furthermore, with each recurrent herniorrhaphy, the chance of rerecurrence increases. A recurrent herniorrhaphy should, therefore, not be undertaken by a surgeon lacking thorough familiarity with and knowledge of the surgical anatomy of the inguinal region. It is also most important to avoid a preconceived idea as to what has been done previously, and, more important, what needs to be done.

Several sequential steps should be taken in the repair of a recurrent hernia. The first is the identification and mobilization of the cord structures. If a Halsted repair was initially performed, the cord structures will, of course, lie immediately below the skin. Care must even be taken with the skin incision so as not to damage these structures. If the cord lies beneath the external oblique fascia, it may be encased in scar tissue. A direct approach in the middle of the external oblique fascia, in the region of the old scar, should then be avoided. Under these circumstances the

surgeon should direct his attention superiorly or inferiorly in "virgin territory" to identify the cord. This can be done by dissection distally beyond the pubic tubercle with identification of the cord structures as they enter the scrotum.

After the cord structures are mobilized and taped, the sac is located and dissected free from its point of emergence through the floor of the inguinal canal. After the sac has been opened, careful digital exploration from within the peritoneal cavity is performed in order to exclude any secondary sac, direct defect, or femoral hernia. A decision must then be made as how best to handle the defect in the floor of the inguinal canal. This decision is one of the most important in the successful repair of both primary and recurrent hernias. Too often, single interrupted sutures are used to "reapproximate the edges of the defect." If the edges of the defect are not carefully dissected back from *beneath*, in order to obtain strong transversalis fascia, the repair is apt to be unsuccessful. All too frequently, interrupted approximating sutures are placed in overlying muscular edges and not in transversalis fascia, and therefore may not hold. In addition, if the patient is operated upon under general anesthesia with muscle relaxants utilized, a false impression of the laxity of the defect and the ease with which approximation is accomplished may be obtained.

If no hernial sac is present, but rather an attenuation of the floor of the inguinal canal as occurs with a direct hernia, the same two pitfalls may be encountered. Both of these problems can be obviated by the use of the Shouldice method for inguinal hernia repair. This method has previously been described in detail.[3] In most patients local anesthesia is used. Tissue tension can then be assessed accurately. In addition, the patient can be instructed to cough at will, further delineating any weaknesses or defects previously unsuspected. At the conclusion of the hernia repair, coughing may be used to test the strength of the posterior wall and the tightness of the internal ring.

The basic principle of the Shouldice technique for the actual hernia repair is complete incision of the transversalis fascia (floor of the inguinal canal) throughout its length, from the internal ring to the symphysis pubis. Dissection is then carried back on the *underside* of the medial divided edge of the transversalis fascia until good firm tissue is obtained. This may require continuing the dissection back to the point where the transversalis fascia fuses with the posterior rectus sheath. The Shouldice repair then imbricates the lateral divided margin of the transversalis fascia beneath the medial margin, and thence the conjoined tendon and internal oblique muscle to the shelving margin of Poupart's ligament. This becomes a four-layer repair, using continuous wire or synthetic nonabsorbable sutures. If there is any question of tissue tension, there should be no hesitation in making a relaxing incision in the anterior rectus sheath medial to the internal oblique muscle.

Transection of the cord and/or orchidectomy should rarely be necessary in order to achieve a good repair. Even the elderly patient accepts orchidectomy reluctantly. If the cord is transected, the testicle devoid of its major blood supply and supporting structures may be the source of prolonged swelling and discomfort. Adequate tissue for reconstruction is

almost always available, so that obliteration of the internal ring is not required.

The use of prosthetic materials such as a synthetic mesh as an adjunct in recurrent herniorrhaphy is rarely necessary. If adequate time is taken, proper identification of the transversalis fascia should always be possible. With medial dissection then carried out from beneath, a strong tissue repair can almost invariably be accomplished.

When the Shouldice herniorrhaphy has been used as the method of repair in primary inguinal hernias, the overall recurrence rate as reported by Glassow in over 50,000 patients from 1945 to 1967 is 0.7 per cent. Since 1951, this has been reduced to 0.4 per cent in his series.[2] In his experience with recurrent hernias repaired by the Shouldice method, the incidence of recurrence in nearly 7000 patients is approximately 1.0 per cent.[1]

The authors have employed the Shouldice method for the repair of both primary and recurrent inguinal hernias since 1955. The overall incidence of recurrence in 953 consecutive inguinal herniorrhaphies has been 0.7 per cent. The recurrence rate in 76 consecutive recurrent inguinal herniorrhaphies during this period has been 2.6 per cent. Over 95 per cent of all herniorrhaphies were performed under local anesthesia. The suture material employed was stainless steel monofilament wire in the first 123 patients, teflon-impregnated dacron in the next 602, and polypropylene in the last 228. Prosthetic material was required in only one recurrent herniorrhaphy, a patient with a six-times recurrent hernia. The follow-up in this series of patients is nearly 100 per cent.

CONCLUSIONS

The repair of a recurrent inguinal hernia is always challenging, and its successful accomplishment extremely rewarding.

Factors influencing the development of recurrent hernias include: (1) patient and physician delay in obtaining proper initial treatment, (2) improper and/or inadequate operative techniques, (3) improperly qualified surgeons, (4) chronic pulmonary disease, and (5) wound infection.

The repair of a recurrent inguinal hernia should be reasonably uncomplicated if certain basic technical procedures are followed.

The Shouldice method of hernia repair represents an important contribution to the surgical management of recurrent hernias.

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Pilonidal Cyst and Sinus

Radical Excision and Primary Closure

*Edgardo S. Alday, M.D.**

The surgical treatment of pilonidal cyst and sinus has remained controversial, for there is no one technique which has proved universally successful or applicable. Despite this controversy, this condition has been taken very lightly, with the most junior resident usually responsible for the operative treatment and postoperative care of the patient. This lesion deserves more attention, not only because of the great divergence of opinion regarding the surgical technique, but also because of the high incidence of recurrence and because of wound infection.

The surgical procedures that are currently being used in the handling of pilonidal cyst and sinus are: (1) complete excision of the cyst and sinus tract, leaving the wound open; (2) complete excision and partial closure of the wound; (3) complete excision, followed by primary wound closure.

In almost all instances, the elliptical excisions are carried along the longitudinal axis of the body. The author prefers a 45 degree elliptical excision of the pilonidal cyst and sinus tract, with primary closure of the wound for both the first occurrence and any thereafter.

EXPERIMENTAL MODEL

Two rubber sheets, each measuring 10 × 14 inches, were mounted along the 10-inch side on a piece of wood. An elliptical portion, measuring 4 × 1.5 inches, was cut out in the center of the rubber sheet, one portion placed vertically and the other placed at a 45 degree angle. The resulting defect was closed with equal numbers of sutures, using +0000 silk sutures placed at equal distances, in an interrupted manner. The rubber sheet was then stretched and showed the following: on the vertically placed elliptical excision, the edges were gaping along the entire length, thereby demonstrating tension in the entire incision. However, in the obliquely placed elliptical excision no gaping edges were noted; rather the edges overlapped on both ends (see Fig. 1).

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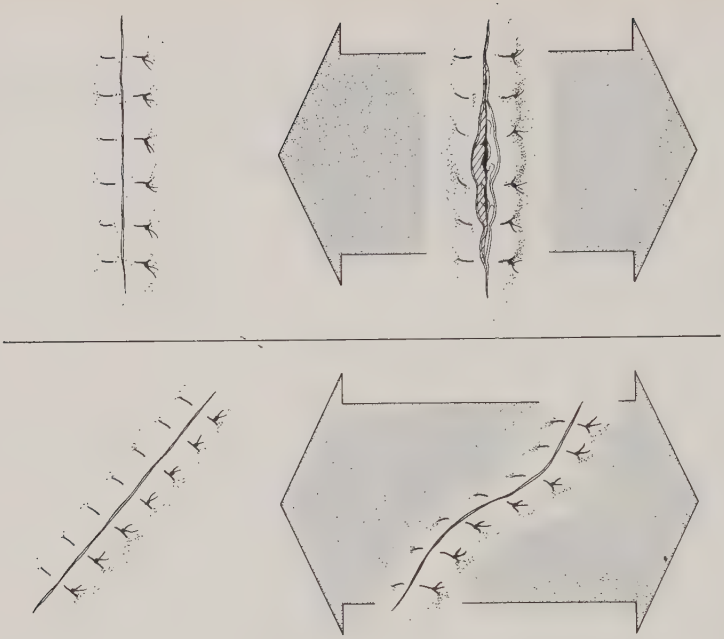

Figure 1. Drawing shows the importance of the direction of the elliptical excision (45 degrees oblique) when the sutured wound is subjected to tension.

PROCEDURE AND TECHNIQUE

There is no special preoperative preparation of the patient. Laxatives are given on the night before surgery, and soap suds enemas on the morning of surgery. In those patients with gross abscess formation, incision and drainage under ethyl chloride spray anesthesia are done on an out-patient basis, and the patient is placed in hot sitz baths for 20 to 30 minutes three times a day. Cultures and sensitivity tests are also performed. As soon as the active inflammatory process has subsided, usually after about 7 to 10 days, the patient is admitted for definitive surgery.

The patient is placed under general anesthesia in a modified jackknife position, with the sacrococcygeal region uppermost. The buttocks, sacral area, and perineum are prepared with betadine solution and draped in the usual manner. The pilonidal sinus is closed with a single purse-string suture of +00 silk. The field is reprepped with betadine solution. The 45 degree elliptical area of excision is marked out with methylene blue. The pilonidal cyst and sinus are then excised completely. An incision is made along the marked area, and is then deepened, down to the sacrococcygeal fascia in the midline and to the fascia of the gluteus maximus muscles on both ends of the incision (Fig. 2). The specimen is sharply dissected, is removed en bloc, and is immediately taken from the operative field. Hemostasis is then achieved by electrocautery. The wound is closed in one layer with through-and-through +000 wire mat-

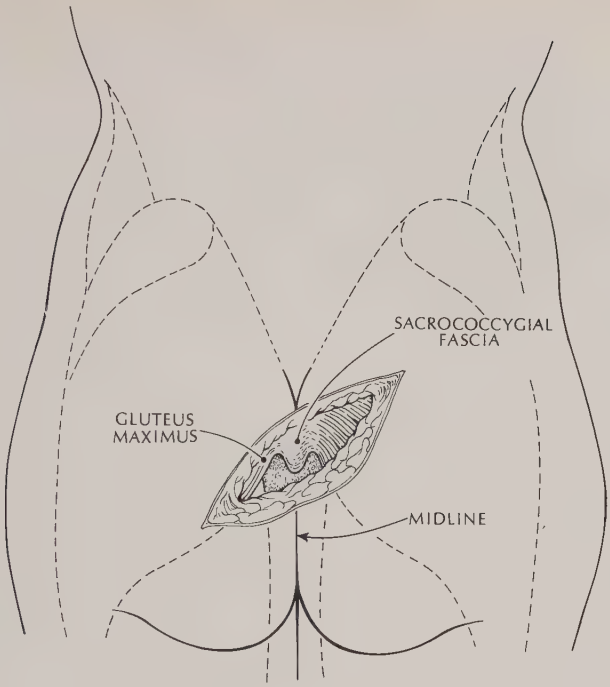

Figure 2. The anatomic extent of excision.

tress sutures, with the knots alternating from one side of the incision to the other.

The suture that crosses the midline is sutured to the sacrococcygeal fascia. Sometimes it is necessary to place an interrupted simple suture of +00000 wire between the mattress sutures to facilitate perfect approximation of the edges. A bolus consisting of 4 × 4 gauze pads rolled in Xeroform gauze is prepared. The bolus is then tied over, utilizing the wire from the through-and-through mattress. A sterile dressing is then applied to the entire area (see Fig. 3).

POSTOPERATIVE MANAGEMENT

There is no special postoperative wound care. The patient is advised to get out of bed on the first postoperative day. The bolus is removed on the sixth postoperative day. The sutures are removed, on the average, on the twelfth postoperative day.

DISCUSSION

The tension of the skin overlying the sacrococcygeal region is in the transverse direction when an individual assumes a sitting or bending

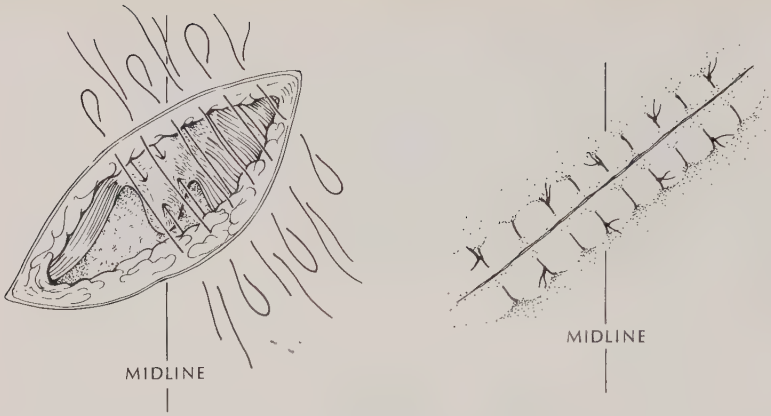

Figure 3. Drawing shows the single layer of wire mattress sutures placed alternately. Perfect approximation of wound edge is attained without tension. The roll of gauze which is routinely tied over the wound is not shown.

position. In almost all the different surgical procedures done for pilonidal cyst and sinus, the elliptical excisions have been carried along the longitudinal direction. Monro and McDermott recommended Z-plasty in all cases of pilonidal cyst and sinus, including recurrent ones.[2] According to the authors, the Z-plasty obliterates the natal cleft by flattening it, directs hair points away from the midline, leaves no midline scar, prevents maceration, reduces suction effects in the soft tissue of the buttocks, and minimizes friction between their adjacent surfaces. In 1946, Gibbon and Freeman[1] described a technique for the surgical treatment of bedsores in the sacrococcygeal region. For a small ulcer, 1 to 2 cm. in diameter, an oblique elliptical excision and the resulting defect were closed by mobilizing the skin margins and suturing them together in a straight line. For large ulcers, a long curved extension of the incision was made on each side, beginning at the point where the tips of the original incisions met. The concavity of the curve was reversed on the opposite side. The incision was carried down through the subcutaneous tissue to the fascia overlying the gluteus maximus muscle. The skin and subcutaneous tissue flaps were then widely mobilized, using fascia and the fat as the plane of cleavage. After mobilization, the flaps were rotated and drawn toward one another.

The experimental model shows the tension along the entire suture line as manifested by gaping edges where the elliptical excision was placed vertically; however, where it was placed at a 45 degree angle, there are no gaping edges but rather overlapping edges at both ends. By utilizing this technique, the author found it unnecessary to free and undermine the skin edges or to create a bilateral rotational flap in order to get a good approximation.

The 45 degree elliptical excision offers the following advantages: (1) all the advantages of the Z-plasty as described by Monro and McDermott; (2) no incidence of skin necrosis as in Z-plasty, since there is no sharp angle incision; (3) practically no tension along the suture line; (4) lastly,

direction of the lower end of the incision away from the anus, thus permitting less contamination and wound infection.

SUMMARY

The experimental model shows the tension along the entire suture line as manifested by gaping edges where the elliptical excision was placed vertically; however, where it was placed at a 45 degree angle there are no gaping edges but rather overlapping edges at both ends. The advantages of the 45 degree elliptical excision in the treatment of pilonidal cyst are presented.

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Vesico-Enteric Fistulas

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Vesico-enteric fistulas have been known to the medical profession for centuries. They were first described in detail as to etiology, pathology and treatment in the British literature in the late nineteenth century. However, it was not until more refined techniques in intestinal and urologic surgery evolved that progress was made in the complete correction of this relatively uncommon surgical problem.

Collected reviews were common in the 1920's and 1930's from the Mayo Clinic and other leading medical centers in this country. Treatment consisted of an intestinal diverting procedure, usually a transverse colostomy.

With our present surgical knowledge, the patient with this distressing problem, when due to benign disease, can look forward to complete correction with low morbidity and mortality.

Certain basic principles must be observed. This report concerns 28 cases managed over a 10 year period.

INCIDENCE

The average hospital can expect two or three cases for every 10,000 admissions. Males predominate over females in a ratio ranging from 3:1 to 5:1. Our own recent series was 19 males to 9 females. However, this included 3 patients with radiation necrosis for female pelvic cancer.

The uterus is thought to protect the bladder from the intestinal disease process by its usual anatomic interposition. This may be altered by the higher incidence of hysterectomy in our present population and, indeed, some recent series show a ratio approaching 50–50.

ETIOLOGY AND PATHOLOGY

In the late nineteenth century tuberculosis, amebiasis, and syphilis were the common causes in the described cases. These are almost un-

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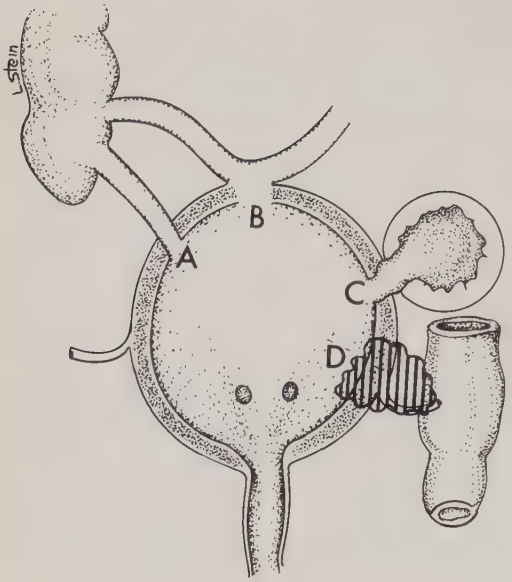

Figure 1. Schematic drawing of vesico-enteric fistulas: *A*, vesico-appendiceal; *B*, ileovesical; *C*, colovesical; *D*, rectovesical.

known at the present time. Diverticulitis is by far the most common underlying pathology. Cases of vesico-appendiceal fistula which have been reported have always been due to a neglected or overlooked appendicitis with rupture. There were 19 cases of diverticulitis with two cases of Crohn's disease in our series. Carcinoma of the sigmoid was present in 6 cases. Radiation necrosis associated with treatment for female pelvic malignant disease comprised 3 cases.

The fistula is initiated by ulceration and inflammation of the bowel wall with subsequent perforation and extramural suppuration from whatever the underlying cause happens to be. The route is determined by the anatomic pathway available and, fortunately, is usually located on the dome of the bladder. In malignant cases, where operable, this allows for adequate bladder resection with preservation of bladder function. However, none of our 6 patients with colon carcinoma survived more than 5 years, the longest survival being 4½ years, with an average of 2 years. This is thought to reflect the advanced stage of colonic carcinoma.

CLINICAL FEATURES

Urinary symptoms predominate the picture, with recurrent cystitis the most common feature. This was present in over 50 per cent of our cases. The delay in diagnosis of the fistula in our series ranged from several weeks to 18 months.

Pneumaturia is a pathognomonic sign and was present in 21 of 28 cases.

Fecaluria was present in 15 cases.

The intestinal signs were silent in over half of our cases and when manifested were relatively nonspecific. Pain and alteration in bowel habit were the most common. Three with carcinoma of the sigmoid complained of bloody stools in conjunction with their urinary symptoms. There was no bleeding with the 17 cases of diverticulitis and 2 of Crohn's disease. Interestingly enough, the 2 cases of Crohn's disease were diagnosed as "spastic colitis," thought to be related to the tension of their recurrent urinary symptoms. The ages of these patients were 32 and 34. The delay in one was 18 months in spite of having seen three separate urologists. The three cases due to radiation necrosis followed cobalt therapy and also had a finding of residual tumor. Both probably contributed to this disorder.

CLINICAL INVESTIGATION

The patient with a suspected vesico-enteric fistula demands the efforts of both the urologist and surgeon. Since urological symptoms predominate, the urologist is usually consulted first. This was the case in 24 out of 28 of our cases. Cystoscopic examination of an incipient fistula simply shows a hyperemic area of bladder mucosa. Later it becomes surrounded with bulbous edema and papillomatous proliferation of the mucosa. The fistula was demonstrated by dye on barium enema studies in only 11 of our 28 cases. Biopsies should be taken where tumor is suspected. Urine cultures and sensitivity studies to antibiotics should be done. The most common organism is E. coli which was present in 26 of 28 patients. Bimanual pelvic and rectal examinations frequently reveal a tender extravesical mass. If general anesthesia is used for cystoscopy, palpation of a mass is simplified.

Sigmoidoscopy was revealing in only the 3 cases of radiation necrosis. This is easily explained by the distortion and angulation of the intestinal tract associated with the development of a perimural abscess preceding the development of a full-blown fistula. It is hoped, by the author, that with the acquisition of the flexible fiberoptic scope a more accurate preoperative evaluation and demonstration of the underlying pathology can be made.

Barium enema examination revealed colon pathology in all cases. However, in more than half, this was not striking and in only six of the 19 diverticulitis cases was a fistulous tract demonstrated by this method. In the 6 sigmoidal carcinomas, all tumors were demonstrated.

In our two cases due to ileitis, the diagnosis was delayed 4 months in one and 18 months in the other because of a failure to obtain barium studies of the small bowel.

FACTORS DETERMINING CHOICE OF SURGICAL PROCEDURES

The etiology, extent of pathology, degree of bowel obstruction as well as toxicity from massive bladder infection all enter into the decision as to a one-stage versus a multi-stage procedure. Here again, bimanual examination is our best method for determining the extent and secondary involvement of other structures by the fistulous process.

Of our 17 cases due to diverticulitis, 12 underwent a three-staged procedure. The one death occurred in a 78 year old woman with advanced emphysema who suffered cardiac arrest in the operating room, was resuscitated, and died a cardiac death 6 days after operation. One case, an 84 year old man, with the only symptom of pneumaturia and diverticulosis on barium enema examination, was not operated on, and died 2 years later of a cerebral accident. Of the 5 patients with diverticulitis who underwent primary resection and closure of the fistula in one stage, there was one death from a disruption of the anastomosis and its subsequent peritonitis. Only 4 of the 6 primary colon carcinomas were resectable—2 by a one-stage procedure and 2 preceded by a diverting colostomy. There were no deaths in this group. Two patients with nonresectable lesions died within 2 months, one with a colostomy and one without.

Our 2 patients with Crohn's disease underwent one-stage procedures and had uneventful recoveries. However, one has had a recurrence of his granulomatous enteritis 5 years after resection.

DISCUSSION

One must keep his options open when dealing with this complicated problem. Any attempt to short-cut hospitalization or a patient's repugnance to a temporary colostomy, against better judgment, will frequently lead to disaster. Patients selected for a one-stage colon procedure should have little or no obstruction, and the ends of resection should be free of edema and inflammatory disease. Antibiotics will not prevent leakage of an ill-conceived anastomosis. The finding of an extra colonic-pelvic collection or extensive inflammatory involvement of other pelvic viscera are indications for a staged procedure.

The time interval between the diverting colostomy and resection is variable. In our group it varied from 10 days to 3 months. In patients with carcinoma the average time interval was 14 days. These patients usually have less inflammatory reaction. One point which we have found useful in tumor cases, where a wide area of bladder must be resected, is to use not only catheter but also suprapubic drainage. This helps maintain adequate drainage of the urinary system in the presence of blood clots forming in the bladder after wide resection. Fortunately, the tumor usually invades the dome and leaves the trigone free. The suprapubic drain can be removed in 5 to 7 days and the catheter drainage in 14 days.

In diverticulitis cases the fistulous opening into the bladder needs only to be closed with one or two sutures of catgut and catheter drainage maintained for approximately 14 days for complete healing. The sigmoid

resection is handled like any primary end-to-end anastomosis without pelvic drainage unless large raw areas are opened up or purulent collections are encountered during the second stage.

If pelvic drainage after bowel resection is felt indicated following a one-stage procedure, then the surgeon probably has made a poor choice and a staged procedure would have been preferable.

If omentum is available, it is deemed advisable to interpose it between the bladder repair and the bowel anastomotic line. In one of our cases involving diverticular disease, a secondary vesicocolic fistula developed 6 months later, requiring further colon resection. This might have been prevented by such a maneuver.

The 2 patients with Crohn's disease and fistulas did very well following a one-stage procedure; however, recurrence of the ileocolitis is high, between 30 and 50 per cent of the cases resected. Therefore, it is our present policy to place these patients on maintenance doses of Azulfidine almost indefinitely and under the care of a gastroenterologist. Evidence of its value has been mounting with a lowered recurrence rate.

SUMMARY

Vesico-enteric fistulas are a challenge to both urologist and general surgeon. The awareness of the possibility of enteric origin of recurrent urinary symptoms should help us prevent the long delays seen in diagnosis. Intestinal symptoms may be vague and minimal. Thorough and accurate preoperative evaluation, including use of the newer fiberoptic colonoscope, will help us make the proper selection as to a one-stage or multi-staged repair. There is room for both in the surgeon's armamentarium, and a wise decision can produce excellent results as seen in this series. When the fistula is of malignant origin, the long-term prognosis remains poor as in any colonic carcinoma that has extended beyond the serosa and involved a contiguous organ. Fistulas secondary to radiation necrosis or recurrent tumor have an extremely poor outlook with some palliation afforded by a diverting colostomy. Patients with fistulas due to diverticular disease and, to a lesser extent, Crohn's disease can look forward to complete correction with a low mortality and morbidity when sound, basic surgical judgment is followed.

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Approach to Bladder Neck and Urethral Obstruction in Women

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A problem frequently encountered by the urologist is the woman with the symptoms of disturbed micturition. In some cases, the abnormal voiding pattern exists alone, unaccompanied by urinary tract infection. In others, the voiding symptoms may coincide with the onset of acute cystitis or urethritis. However, a significant number of patients manifest an abnormal voiding pattern prior to the first clinically apparent infection. In still other patients, those with recurrent lower or upper urinary tract infections, careful history-taking will reveal abnormalities of voiding in the "normal" intervals between infections in many.

We have found that the common denominator in the majority of these patients has been the presence of what can be termed vesicourethral obstruction. Admittedly, the dynamics of this entity are incompletely understood. In many cases, an obvious mechanical obstruction, usually urethral, can be located and removed. In others, a functional obstruction resulting from imbalance between intravesical pressure and urethral resistance must be presumed, without detectable mechanical urethral stenosis. In the latter group, the beneficial results of urethral widening serve to confirm the presence of this functional obstruction. In both groups, then, the mechanically obstructed and the functionally obstructed, therapy is directed toward reducing urethral resistance.[5]

Stenosis of the urethra is most often a developmental anomaly. Meatal stenosis is thought to result from persistent malformation of the cloacal membrane.[18] Urethral or meatal stenosis may also occur as a sequela of inflammatory disease of the paraurethral glands and their ducts. Contracture of the vesical orifice is probably a local manifestation of generalized hypertrophy of the bladder detrusor musculature secondary to urethral obstruction.[8] However, inflammatory change[3] and myogenic or neurogenic dysfunction may also be contributory to vesical neck obstruction.

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DIAGNOSIS

History

The most valuable clinical tool for reaching a presumptive diagnosis, usually correct, of vesicourethral obstruction is the history. History-taking must be detailed and persistent, since symptomatology may be subtle.

The records of 51 women with a degree of urethral meatal stenosis sufficient to require meatoplasty were reviewed for symptomatology. The patients ranged in age from 20 to 85 years, with a mean age of 39. Of these, 27 (53 per cent) had recurring episodes of cystitis. A history of acute cystitis, particularly if prolonged or recurring, is highly suggestive of correctible vesicourethral obstruction. Flank pain or fever is unusual in cystitis alone; their presence usually indicates an associated pyelonephritis or systemic involvement, rendering the clinical situation somewhat more serious. Five patients in the group studied (10 per cent) had at least one documented episode of pyelonephritis

Since vesicourethral obstruction is often congenital, women should be questioned for their recollection of childhood or adolescent enuresis. This symptom was reported by 6 patients (12 per cent). Urinary infections, repeated abdominal pains, unexplained fevers, or voiding difficulties also suggest congenital obstruction.

Often patients have not had their urinary infections documented by bacteriologic examination. Questioning is then directed toward identifying and characterizing possible episodes of cystitis. Periodic dysuria, most pronounced at the end of micturition, and often mild and transient, may be the only indication of vesical inflammation. Painful hematuria is another common symptom of cystitis, usually sufficiently alarming to prompt the patient to seek attention. Frequent passage of small volumes, urgency, and a persistent sensation of incomplete bladder emptying often characterize the episodes of cystitis, each symptom signifying compression of proprioceptive sensory nerve endings in the bladder by inflammatory edema. Similarly, response to urinary antibacterial agents is indirect evidence that the episodes represented true infections.

It is important to determine if the irritative bladder symptoms are preceded and accompanied by vaginal itching or discharge, as localized urethral irritation from vaginitis may mimic true cystitis to some degree.

Questioning is then directed to the patients' "normal" voiding pattern. It is constantly surprising how often this phase of the history yields positive symptomatology. The 51 women requiring meatoplasty were specifically questioned for symptoms present during intervals between acute exacerbations of infection when the patients considered themselves well. The voiding pattern was also noted in patients in the meatoplasty group who had not manifested urinary infections.

The symptoms elicited are listed as percentages in decreasing order of occurrence.

Frequency (80 per cent) indicates vesical hypertonicity owing to either mild vesical inflammation or compensatory detrusor hypertrophy in response to outlet obstruction. The patients admitted to the need to void every 1½ to 2 hours or less, regardless of fluid intake and often with small volumes. Frequency was often present without bacteriuria at the time of

initial office examination, suggesting that the latter mechanism is operative in many women. This situation corresponds to the frequency pattern evidenced by many males with prostatic obstruction without infection. Residual urine is usually minimal and is unlikely to be a significant factor in causing frequency in women.

Urgency (65 per cent), a more subtle symptom, is rarely volunteered by the patient but readily elicited. This symptom, as with frequency, reflects vesical irritability. Urine examination helps to differentiate inflammatory from myogenic urgency.

Nocturia (57 per cent), usually occurring in association with diurnal frequency, also indicates vesical hypertonicity.

Dysuria (55 per cent) signifies edematous compression of sensory receptors for pain within the bladder wall. Mild and transient dysuria occurring during "normal" periods suggests a bacterial cystitis generating a mild inflammatory response. The dysuria is characteristically terminal, becoming most manifest as the bladder completes its contraction.

Sensation of incomplete bladder emptying (47 per cent) is often a mild but highly significant symptom. The persistent urge to void may in fact indicate the presence of residual urine, but more often reflects continuing stimulation of proprioceptive nerve endings in the bladder by inflammation or hypertonic musculature.

Flank pain (33 per cent) suggests renal parenchymal infection, particularly if accompanied by fever, chills, and infected urine. However we have noted that flank pain may in some instances be related solely to the presence of vesicourethral obstruction, without associated urinary infection or vesicoureteral reflux. Often the pain increases as the bladder fills and is relieved to some degree by voiding. Urethral instrumentation may transiently reproduce the flank pain and the symptom often disappears after urethral widening. The precise mechanism of this pain is unclear, but may relate to the anatomic observation that the ureteral musculature continues through the trigone and vesical orifice into the urethra.[20] Irritation or hypertrophy of this musculature in its vesical or urethral portion may cause referred pain in the renal area by nervous pathways as yet incompletely identified.

Urgency incontinence (31 per cent) indicates vesical hypertonicity. Here, the sensory afferent stimuli from the bladder wall to the micturition center in the sacral spinal cord are sufficiently powerful to overcome cortical regulation of the micturition reflex. Involuntary voiding, usually partial, occurs in association with a strong urge. The symptom is easily ascertained by questioning. It is important to distinguish urgency incontinence from stress incontinence when corrective surgery is contemplated. With urgency incontinence the basic problem is obstructive and therapeutic efforts should be directed toward relieving the obstruction. Operations which tend to increase urethral resistance, such as vesicourethral suspension, should be studiously avoided in cases of urgency incontinence, since the degree of obstruction may be compounded.

Hesitancy (24 per cent) is another subtle but informative symptom. The patient admits to being aware of having to wait unduly long for voiding to begin, often despite a strong urge to void. The symptom reflects a delay in the ability of the bladder detrusor to produce an in-

travesical pressure higher than intraurethral pressure. This may result from a severe stenosis which resists the contractile pressure of a hypotonic, normal, or even hypertonic detrusor. Urethral inflammation involving the region of the external sphincter may inhibit relaxation of that structure. Also, vesical inflammation may cause the patient to refrain from voiding in anticipation of dysuria.

Stress incontinence (22 per cent) is usually associated with cystourethrocele. However, this symptom occasionally seems more related to urethral stenosis than to cystourethrocele, in that urethral widening alone sometimes corrects the condition. The precise mechanism is as yet unclear. Stress incontinence in these cases may have developed as a result of dilation of the urethra proximal to the stenosis, with diminution of closing pressure in the proximal area. In some instances, careful interrogation will reveal that the symptom is actually stress-urge incontinence. Here, a sudden rise in intra-abdominal pressure is transmitted to the filled bladder, causing an uncontrollable urge to void.

Suprapubic pain (20 per cent) is present with a full bladder and is relieved by voiding, or is noted at the end of micturition. The symptom suggests vesical inflammation, but is occasionally noted with marked detrusor hypertrophy alone.

Straining to void (16 per cent), with voluntary intra-abdominal pressure added to augment contractile emptying of the bladder, is normally a smooth muscle, involuntary function. The symptom indicates that the detrusor is incapable of exceeding intraurethral resistance either because of obstruction, vesical hypotonicity of myogenic or neurogenic origin, or both.

Slow stream (14 per cent) often goes unnoticed by the patient with congenital urethral stenosis since the symptom may have been life-long. Patients frequently remark on a considerable increase in voiding flow after urethral widening, when in fact their flow has merely reached the normal rate for the first time.

Interrupted stream (10 per cent) indicates the inability of the detrusor to sustain its contraction until the bladder is empty, as is normally the case. This symptom occurs as a result of marked obstruction, often with vesical hypotonicity. Periurethral inflammation with spasticity of the external urethral sphincter may cause voluntary interruption of the stream.

Infrequent voiding (10 per cent) is characteristic of the hypotonic bladder. Intravesical pressure remains low until the bladder volume is large, so that stimulation of proprioceptive sensory receptors within the bladder wall is delayed. The patient regularly voids at intervals of 6 to 8 hours or more, despite normal fluid intake. The symptom is often present since childhood, is not significant or distressing to the patient, and must therefore be elicited by questioning.

Dyspareunia (6 per cent) apparently occurs secondary to localized inflammation of the urethra or periurethral glands. Distal obstruction may give rise to turbulent flow of urine within the urethra during voiding, with inadequate washout of bacteria.[9]

Fever (4 per cent) indicates urinary infection with possible renal or systemic involvement, as noted previously.

Acute retention (4 per cent) is a relatively uncommon symptom in the female. Thus, vesicourethral obstruction and/or vesical hypotonicity in women differs from the situation in males with bladder outlet obstruction. Inability to void is unusual in women, but infection secondary to partial obstruction is far more common.

In some patients, urinary infection may develop in association with single, intermittent or, more usually, indwelling catheterization. Persistence of infection following removal of the catheter is highly suggestive of preexisting vesicourethral obstruction, since bacteriuria should clear quickly in normal individuals.[4] We have found that on close questioning, the majority of these patients disclose prior voiding abnormalities.

We have noted, as have others,[14] that obstructive uropathy is often a familial disorder, so that women should be questioned regarding urinary tract infections or voiding disorders in relatives.

It is emphasized that the above symptoms may be present singly or in various combinations and not necessarily in relationship to the severity of obstruction. Any of these symptoms, however, suggests a vesicourethral abnormality and further diagnostic steps are indicated.

Physical Examination

Physical findings in women with vesicourethral obstruction are usually scant. Flank tenderness may be evident if renal inflammation has occurred. Mild suprapubic tenderness is not uncommon and may be present without accompanying urinary infection. The bladder rarely exhibits percussible residual urine. The urethral meatus may appear stenotic, but detection is usually difficult visually. Inflamed periurethral glands may be swollen and tender. If vaginal erythema and discharge are noted, a possible causal relationship of vaginitis to voiding symptomatology must be explored. Neurologic examination is performed to determine if the disturbance in micturition is related to a deficit of innervation.

Laboratory Studies

Overall renal function is not usually impaired in women with vesicourethral obstruction, but a blood urea nitrogen, serum creatinine, or phenolsulfonphthalein determination should be obtained to be certain.

Urinalysis is performed, including examination of the stained urinary sediment, to determine if an infection is present. Wet smear examination alone is often inadequate to detect bacteriuria and detection is important. We prefer to obtain a catheterized sample to eliminate the very real possibility of vaginal or vulvar contamination of a voided sample. A No. 10 French or No. 12 French straight catheter is used to minimize discomfort and post-catheterization urethral edema. Not infrequently, patients referred because of bacteriuria noted repeatedly on voided samples prove to be uninfected when catheterized urine is examined. If, and only if, bacteria are found on stained urinary sediment, culture and sensitivity studies are obtained.

X-Ray Studies

Intravenous urography should be performed whenever vesicourethral obstruction is suspected. It is impossible to determine accu-

rately the renal or ureteral effects of lower urinary tract obstruction or infection on the basis of symptomatology. Normal renal function tests may mask unilateral abnormalities. Also upper urinary tract infection may seed bacteria to the lower tract and produce voiding symptomatology secondarily. Therapy must therefore take into account the entire urinary tract and the intravenous urogram provides useful information to this end.

Among the 51 patients who underwent urethral meatoplasty, 7 exhibited urographic evidence of mild unilateral upper tract dilatation of the calyces, pelvis or ureter. One patient had pyelonephritic scarring. Two patients exhibited bladder diverticula and 2 had large capacity bladders.

Residual urine estimated at 5 ml. or more was present in 11. Thus, approximately 80 per cent of patients with a substantial degree of urethral stenosis appeared to empty the bladder adequately by intravenous urography. This finding points up the inadequacy of intravenous urography in the diagnosis of vesicourethral obstruction. Clearly, vesical compensation can empty or nearly empty the bladder in the presence of outlet obstruction. However, a residual urine volume of only 1 to 5 ml. may be adequate to foster infection.[4] Significant residual urine may therefore be present but inapparent by urography. Thus, while positive radiographic findings are useful, a normal intravenous urogram does not rule out significant obstruction.

Urethral Instrumentation, Cystoscopy and Other Studies

Urethral resistance depends primarily upon the caliber of the narrowest point or points in the urethra during voiding. Urethral calibration as performed clinically in the nonvoiding state detects areas of stenosis in the resting urethra. This technique provides indirect but highly useful data regarding likely areas of resistance to urine flow.

The usual method of calibration involves passage of graded sizes of bougies-a-boule via the urethra into the bladder, with subsequent withdrawal. Areas of constriction are recognized by "hang" or resistance to withdrawal of the bougie. In the majority of cases the stricture is located at the meatus,[1, 18] where a ring or thin circular band of tissue is evident, usually more prominent inferiorly. Isolated strictures of the proximal, mid, or distal urethra are not uncommon, and multiple strictures may be encountered. In the group of 51 women undergoing meatoplasty, calibration revealed coexistent stenosis in 34 (67 per cent). The additional narrowing was located in the distal urethra in 20, the mid urethra in 12 and in the proximal urethra in 2. Careful bougienage is required, then, since successful therapy must account for each constriction.

There is some disagreement as to the precise caliber of the normal female urethra and what specific calibration value indicates stenosis.[10] Resistance to passage of No. 22 to No. 28 French instruments is generally accepted as at least suggestive evidence for mechanical urethral obstruction.[2, 12, 16] Of the 51 patients selected for meatoplasty, the urethral meatus calibrated between Nos. 18 and 26 French in 46 (90 per cent).

Clearly, there is overlapping of the "normal" range of calibration values with stenotic values, so that absolute diagnosis by calibration alone is not always possible. Indeed, there are instances when the clinical picture duplicates that of mechanical urethral stenosis except that the urethral caliber is within the normal range. These patients are believed to harbor functional obstructions. The urethra, albeit of normal caliber, constitutes an obstruction to bladder emptying. In both types of obstruction, residual urine remains in the bladder after voiding. The amount may be quite small, particularly in younger women,[7] but enough to promote the development of infections in some. In both mechanical and functional vesicourethral obstruction, urethral widening can be expected to yield significant improvement.

Cystoscopy is an essential step in evaluation for suspected vesicourethral obstruction. The key finding is trabeculation, present in all 51 patients in the meatoplasty group. Trabeculation, reflecting detrusor hypertrophy, indicates that the bladder musculature has been required to increase its contractile force in order to overcome urethral resistance. Regardless of the urethral calibration value, the presence of trabeculation signifies obstruction. An exception may be the trabeculation seen in association with the autonomous neurogenic bladder, where perpetual uninhibited contractions lead to trabecular changes in the bladder wall. However this clinical situation is easily distinguished from the more usual one, vesicourethral obstruction, presently under discussion.

Associated cystoscopic findings commonly include granular, cystic, or pseudomembranous trigonitis, found in 92 per cent of the series, and inflammatory polyps of the proximal urethra, noted in 73 per cent. Contracture of the vesical orifice neck, usually quite minimal, was evident in 73 per cent. The latter diagnosis is admittedly tenuous, since considerable subjectivity is involved in assessing the female vesical orifice.

Assessment of bladder capacity during cystoscopy in the unanesthetized patient provides valuable information regarding vesical hypertonicity or hypotonicity.

Certain other studies are useful in the evaluation of the patient with suspected vesicourethral obstruction. The cystometrogram may help to differentiate neurogenic from myogenic dysfunction of the bladder. Retrograde cystography is employed to determine the presence of low pressure vesicoureteral reflux. Voiding cystourethrography can detect high pressure reflux which occurs during voiding, although many women are unable to void in the presence of radiologic equipment and waiting onlookers. Useful data may also accrue from cineradiographic cystourethrography, intravesical voiding pressure manometry,[15, 17] measurement of the urine flow rate and urethral pressure during voiding[22] and a combination of the latter two procedures to determine urethral resistance.[21]

TREATMENT

Successful therapy in women with disturbed micturition or recurrent urinary infection depends on suspecting vesicourethral obstruction,

identifying it and relieving it. If infection is found at the time of examination, this should be cleared with antibacterial therapy. Urethral dilatation at infrequent intervals often yields dramatic improvement, with return toward a normal voiding pattern and elimination or decrease in incidence of infections. Response to initial dilatation confirms the initial suspicion. In approximately one-third of these patients, however, dilatation may produce excessive discomfort and the benefits are short-lived. These patients are briefly admitted to the hospital, where under general anesthesia, adequate urethral widening can be accomplished. The nature of the procedure is dictated by the findings by bougienage and cystoscopy.

Technique of Meatoplasty

If the obstruction is meatal, meatoplasty is performed. The labia are sutured laterally to the inner aspect of the thighs. With mosquito hemostats, the junction of the urethral and vestibular mucosa is grasped at 4, 6, and 8 o'clock. Using curved iris scissors, a crescentic rim of tissue is excised inferiorly from 4 to 8 o'clock, the excised portion measuring 4 to 5 mm. in width at the 6 o'clock position. The mucosal edges are secured with 3 to 5 interrupted sutures of 4–0 plain catgut. The sutures are placed as the tissue is excised to prevent proximal retraction of the urethral mucosa and are left untied. The urethra is overdilated to No. 45 French with a Köllmann dilator. Any sutures which have torn out are replaced and all sutures are tied. A No. 22 French Foley catheter is left in place overnight to eliminate postoperative dysuria.

Overdilatation

If bougienage discloses that the stenosis is located more proximally rather than at the meatus, simple overdilatation to No. 45 French is accomplished.

Occasionally overdilatation produces a mucosal tear at the meatus. This is usually a short longitudinal defect at 12 o'clock. If noted, the urethral and vestibular mucosa are approximated transversely with a single 4–0 plain catgut suture, to promote healing to a wider caliber.

Endoscopic Surgery

Inflammatory urethral polyps, if extensive, are destroyed by electrofulguration. If the vesical neck appears contracted or corrugated, revision is performed with a stiff electrode.[6]

Follow-Up Care

A urinary antibiotic is prescribed for 10 to 20 days following the procedure. Patients return to the office in 4 to 6 months for repeat urethral dilatation, particularly if proximal narrowings exist and approximately yearly thereafter.

In most instances, the symptoms of vesical hypertonicity or hypotonicity abate once vesicourethral obstruction has been corrected. However, if the bladder has been severely affected, symptoms may persist, albeit usually to a lesser degree. It is then helpful to superimpose bladder training by timed voiding. With vesical hypertonicity in the absence of infection, the patient is instructed to defer voiding for 3 to 4 hour intervals. Bladder capacity generally increases accordingly.

In the hypotonic bladder with large capacity, residual urine may persist despite reduction of outlet resistance. The bladder musculature continues to be overstretched so that its contractility remains impaired. In this situation also, the patient is instructed to void by the clock at 3 to 4 hour intervals, since the urge to void comes infrequently. Residual urine is further reduced by double or triple voiding and occasionally by suprapubic pressure by the Credé maneuver. Bladder stimulation by cholinergic therapy is reserved for recalcitrant cases.

In the presence of coexistent chronic pyelonephritis, long-term antibacterial therapy may be required. The patient is also advised to maintain adequate hydration to promote bacterial dilution and washout. She is instructed to see that episodes of vaginitis are attended to promptly.

RESULTS

Results in 51 women who underwent urethral widening by meatoplasty and overdilatation were reviewed. Data were available in 42 patients followed 6 to 49 months, with an average of 14 months. Of these, 36 (86 per cent) had an excellent result. Fifteen (36 per cent) reverted to a completely normal voiding pattern and those with prior urinary infections remained infection-free. Twenty-one patients (50 per cent) were significantly improved, with rare and mild voiding symptoms usually associated with premenstrual edema and sterile urine. Six patients (14 per cent) continued to experience voiding symptomatology and/or recurrent infections. No patient became incontinent following the procedure and there were no complications.

Comparison of the dilatation caliber attainable with the Köllmann dilator at postoperative visits revealed an increase of Nos. 5 to 11 French over the preoperative caliber, with an average increase of No. 8 French. Thus, in the majority of cases, urethral meatoplasty and overdilatation alone effected striking improvement. At the very least, the procedure permits more adequate dilatation to be carried out in the office with minimum discomfort.

Results are comparable to those reported for internal urethrotomy. Keitzer and Allen noted cure or improvement in 85 per cent of their 800 cases, although 6 patients developed stress incontinence.[11] McLean and Emmett reported a 77 per cent success rate and no incontinence.[13] Tanagho and Lyon found no histologic changes in the canine urethra following dilatation to No. 45 French. However, urethrotomy to No. 32 French resulted in disruption of urethral musculature with dense fibrous tissue replacement at the site. They concluded that dilatation is the preferred procedure since it is not injurious to urethral muscle, causes no change in smooth muscle tone or sphincteric activity and gives as good or better results.[19] Results in our patients tend to support this conclusion.

SUMMARY

We have attempted to emphasize the significant relationship between an abnormal voiding pattern, recurrent urinary infection, and

vesicourethral obstruction in women. Careful history-taking will uncover symptomatology which reflects the pathophysiologic changes which the bladder has undergone as a result of mechanical or functional obstruction. Diagnostic evaluation should include bougienage to locate obstructive lesions and cystoscopy to detect trabeculation, the hallmark of obstruction, and associated lesions. Successful therapy depends on adequate urethral widening for which office dilatation often suffices. If improvement is limited or short-lived, over-dilatation under general anesthesia is recommended, with meatoplasty performed if meatal stenosis is identified.

It is stressed that urethral stenosis is a common lesion. Corrective therapy can be expected to benefit many women who have been persuaded that their voiding disturbances and urinary infections are problems with which they must live.

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The Correction of Post Gastrectomy Malabsorption by Jejunal Interposition

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More than half the patients who undergo subtotal gastrectomy experience some degree of digestive difficulty in the postoperative period.[7-9, 11-13] The majority of these patients can be managed conservatively and their symptoms will subside or improve to a degree that they are no longer bothersome. It has been estimated that in about 12 per cent of patients symptoms are marked and in about 3 per cent they are severe and lasting. After repeated conservative therapy these patients continue to have disability as a result of their subtotal gastric resection. Despite continuing research and voluminous literature published on this subject, the basic mechanism of malabsorption has never been adequately established.

Steatorrhea of variable intensity develops in approximately half of all patients who undergo a Billroth II anastomosis.[14] In a small minority of patients the steatorrhea may be of such proportion as to cause major changes: severe weight loss, hypoproteinemia, avitaminosis, and electrolyte losses.

Previous communications from our Department of Gastroenterology have emphasized the importance of the afferent limb of the Bilroth II anastomoses.[3, 16-18] They have shown an overgrowth of bacteria in these limbs and a direct correlation between bacterial overgrowth and the occurrence and severity of steatorrhea. Furthermore, the administration of a specific antibiotic for the bacteria isolated in the afferent limb which evidences stasis is followed by transient improvement in fat absorption and gain in body weight. Unfortunately in some patients response is not very definite and in others specific antibiotics given in repeated courses lose their effectiveness until patients finally become refractory to this sort of treatment.

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In our experience, the conversion of a Bilroth II to a Billroth I anastomosis has not always resulted in alleviation of symptomatology. Technical difficulties are caused by the presence of a small gastric remnant and/or a very scarred duodenal stump. It also has been shown that the routine use of Billroth I anastomosis does not eliminate the dumping that follows the Billroth II procedure.

MATERIALS AND METHODS

Nine patients, all of whom had severe lasting post gastrectomy symptoms, form the basis of this report. Seven were men, 2 were women; ages ranged from 29 to 61 (Table 1). Eight of the patients had subtotal gastrectomy with a Billroth II gastrojejunostomy. One patient had a gastrojejunostomy with vagotomy without resection. The original surgical procedures had been performed 1½ to 11 years previously. The patients' complaints included anorexia, weakness, anemia and abdominal discomfort, diarrhea, steatorrhea and weight loss. The symptoms were first noted by these patients soon after their original surgical procedures and gradually increased in severity. Two patients (Cases 1 and 3) had suffered symptoms for 8 years; none of the 9 patients was able to carry on their usual activities. All patients had had admissions to various hospitals and had been unsuccessfully treated with drug therapy and dietary regimen. The 9 individuals with steatorrhea and malabsorption had lost between 10 and 80 pounds in weight following gastrectomy. Five patients had intractable anemia. Various degrees of hypoproteinemia, edema, skin rash, chylosis, glossitis, and discoloration of hair, as well as symptoms involving the central nervous system, were present in some patients.

All patients being considered for jejunal interposition were extensively studied by our Department of Gastroenterology. Each had a complete blood count, urinalysis, fasting blood sugar, blood urea nitrogen, alkaline phosphatase, serum bilirubin, protein-electrophoresis, and serum electrolyte determinations. Serum carotene concentration was measured photocolorimetrically. Serum iron was measured according to the method of Peterson.[10] A D-xylose urinary excretion was measured according to the modification of Christiansen.[2] Urinary excretion of cobalt-6 labeled vitamin B_{12} was measured with and without the use of intrinsic factor of known potency. An augmented histamine gastric analysis was performed according to the modification of Baron.[1] A fecal fat determination of a 3 day stool collection was performed by the method of Van de Kamer.[15] Specimens for bacterial analysis were obtained from all patients by intubation of the afferent loop under fluoroscopic vision. The aspirated material was cultured on three media, MacConkey's agar, tellarite agar, and blood azide. Anaerobic growth was checked in thioglycollate broth. Specific antibiotic sensitivity of the predominant bacteria was determined on these cultures.

Our Department of Gastroenterology has previously reported a median bacterial count in post gastrectomy patients of 387,000 colonies per ml. In patients with steatorrhea, 25.6 million colonies per ml. have been

Table 1. *Post Gastrectomy Patients with Steatorrhea Before and After Medical and Surgical Treatment*

PATIENT, SEX, AND AGE	AFTER BILLROTH II (yr.)	DURATION OF SYMPTOMS (yr.)	WT. LOSS (lb.)	HGB. (gm.)	SERUM IRON (mg./100 ml.)	CAROTENE (mg./100 ml.)	PRETREATMENT Fat (gm./24 hr.)	PRETREATMENT Bacterial Colony Count 1,000/ml. *		AFTER ANTIBIOTIC Wt. Gain (lg.)	AFTER ANTIBIOTIC Fat (gm./24 hr.)	AFTER ANTIBIOTIC Bacterial Colony Count 1,000/ml. *		AFTER JEJUNAL INTERPOSITION Fat (gm./24 hr.)	AFTER JEJUNAL INTERPOSITION Wt. Gain (lb.)	AFTER JEJUNAL INTERPOSITION Bacterial Colony Count 1,000/ml. *		YRS. SINCE INTERPOSITION
1. W.L. M, 54	6	2	30	9.8	70	.019	25	92,000	E.C.	9	8	673	A.	5	35	4,500	A.	14
2. J.L. M, 36	11	11	30	12.7	92	.04	19	1,000	H.S.	16	2	500	H.S.	4	28	1,000	H.S.	14
3. J.W. M, 48	1½	1½	80	11	78	.01	16	54,000	A.	5	6	370	E.C.	7	40	400	A.	11½
4. J.S. M, 42	6	6	39	6.7	11	.02	23	36,000	A.	0	3	20,000	E.C.	3	25	3.9	H.S.	14
5. R.O. F, 32	12	5	10	5	18	.038	18	20,000	E.C.	0	8	700	E.C.	3	12	900	H.S.	13½
6. M.C. M, 29	9	9	40	10.8	72	.017	17	7,000	A.	2	3	3,000	H.S.	2	28	14,000	H.S.	13½
7. J.K. M, 57	2	2	26	14.8	130	.05	16	15,000	Ps.	2	6	1,000	H.S.		40	No growth		12
8. A.M. F, 60	4	4	38	13	115	.016	15	1,000	H.S.	2	10	No growth		3.5	11	500	H.S.	12½
9. P.K. M, 61	11	11	20	10.6	55	.019	21	25,000	P.	0	20	1,000	A.	8	5	60	E.C.	13

Predominant Organisms
* E.C., E. Coli
A., Aerobacter
H.S., Hemolytic Streptococcus
Ps., Pseudomonas
P., Proteus

found. Duodenal aspirations of unoperated control persons show 10,000 colonies per ml.

After completion of studies, tetracycline or chloramphenicol, 1 gm. daily for 5 to 10 days was administered to this group of patients. These antibiotics were utilized because all bacteria cultured in this group of patients were sensitive to these antibiotics. One patient (Case 9) had a severe Salmonella derby infection and received antibiotic treatment for 2½ months before the performance of the jejunal interposition. This patient received chloramphenicol, neomycin, terramycin, and erythromycin. When conditions permitted, patients remained on a high caloric diet containing between 70 and 100 gm. of fat a day, supplemented by a multivitamin preparation. After a 10 day course of antibiotic administration, the afferent loop cultures and fat absorption measurements were repeated. Body weight was recorded daily.

From the entire group of patients studied, 9 were selected for surgical correction of malabsorption. Patients were selected for surgical treatment according to the following criteria: (1) failure to show any long lasting improvement with repeated courses of antibiotic treatment; (2) a severe degree of steatorrhea, over 20 gm. of fat in the stool daily; (3) a nutritional disturbance with failure to respond to a single course of antibiotics.

Of importance was the absence of free acid after histamine stimulation in 8 of the patients. In one patient (Case 8), the one referred to as having had a gastrojejunostomy and vagotomy without resection, there was no free acid following insulin stimulation, but 20 mEq. of free acid and a pH of 3 were noted following the two doses of histamine. An antrectomy as well as a jejunal interposition were performed in this patient.

PREOPERATIVE TREATMENT

Concentrated salt free albumin was given intravenously to all patients who demonstrated hypoproteinemia. They were prepared for surgery by showers or abdominal scrubs twice daily. The patients were intubated with long gastric tubes 1 hour prior to surgery.

SURGICAL EXPOSURE

All patients had been operated upon previously through vertical incisions. In some patients the old surgical scar was excised and exposure obtained directly through the old wound. Because of body configuration of other patients, a long transverse abdominal incision, approximately 2½ inches above the umbilicus was made and carried well out into the right flank. Usually the liver, gastric stump, and proximal portion of the gastrojejunostomy were adherent to the peritoneum, anterior abdominal wall, or undersurface of the liver. Wide exposure by careful sharp dissection was obtained and all structures were freed completely. The duodenal stump in the majority of cases was readily exposed and easily opened at

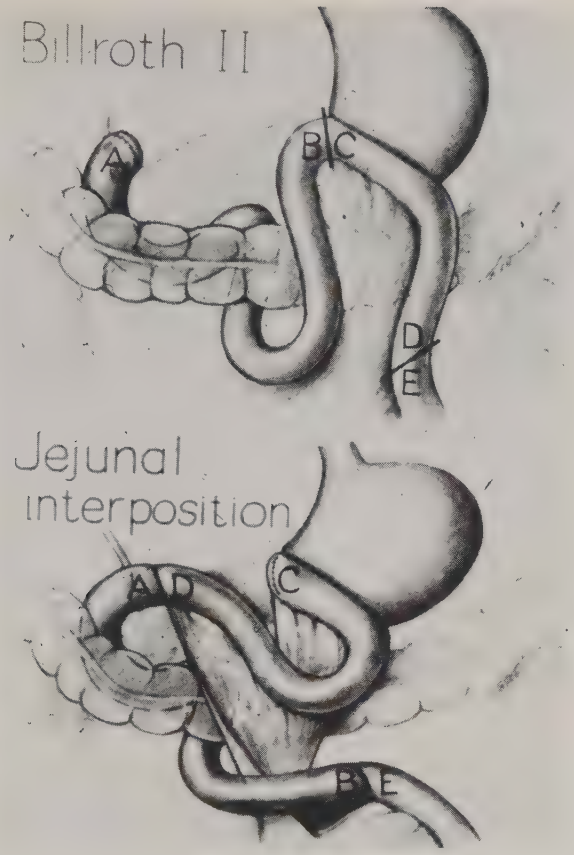

Figure 1. Jejunal interposition. The afferent limb is divided between B and C. C is closed. The efferent limb is divided between D and E. D is anastomosed to A–D jejunoduodenostomy. B is anastomosed to E, jejunojejunostomy.

the site of original closure. In those cases in which the duodenal stump was scarred or buried in the substance of the pancreas, no attempt was made to dissect it out, but an incision made on the anteromedial aspect of the duodenum was utilized for the jejunal duodenal anastomosis.

The entire abdomen was explored carefully and all the internal organs were inspected. Afferent loop kinking, obstruction or adhesions at the site of the gastrojejunostomy were carefully looked for to rule out a mechanical basis for afferent limb stasis.

In 5 patients operated upon, the afferent limb was unusually long. In Case 9, the afferent limb was greatly dilated proximal to an area of partial obstruction at the site of repair of a jejunal perforation which occurred immediately after the original surgery. No evidence of anastomotic ulcers or marginal ulcers was found in any of the patients.

The surgical procedure is outlined in Figures 1 to 7.

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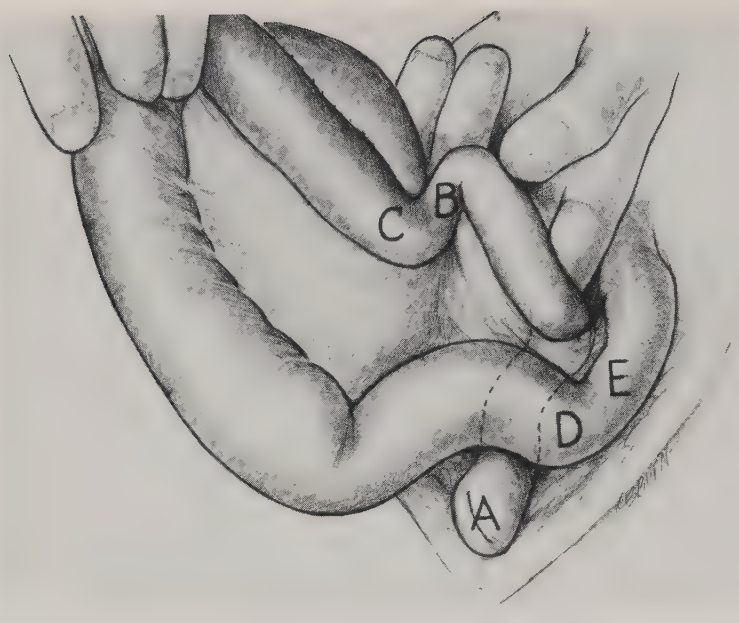

Figure 2. Operative findings after Billroth II anstomosis. A, Duodenal stump; B, End of afferent limb. C and D, afferent limb. E, jejunum.

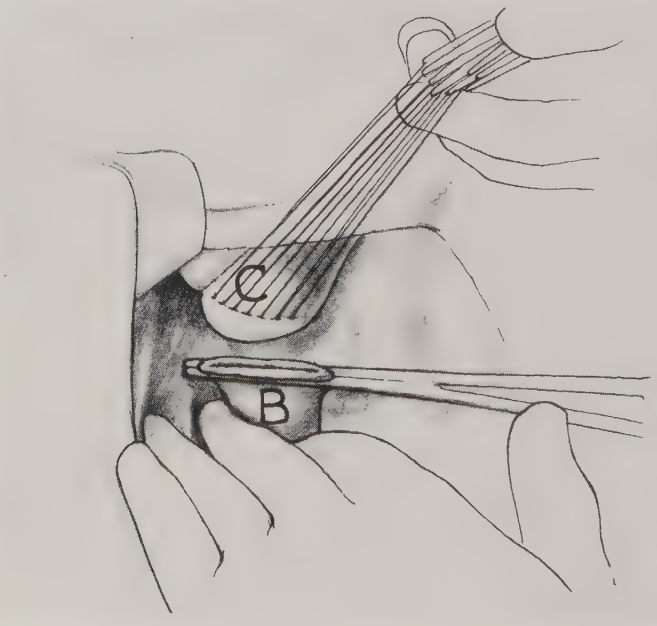

Figure 3. The afferent limb is divided between B and C. The afferent limb is closed at the lesser curvature of the stomach.

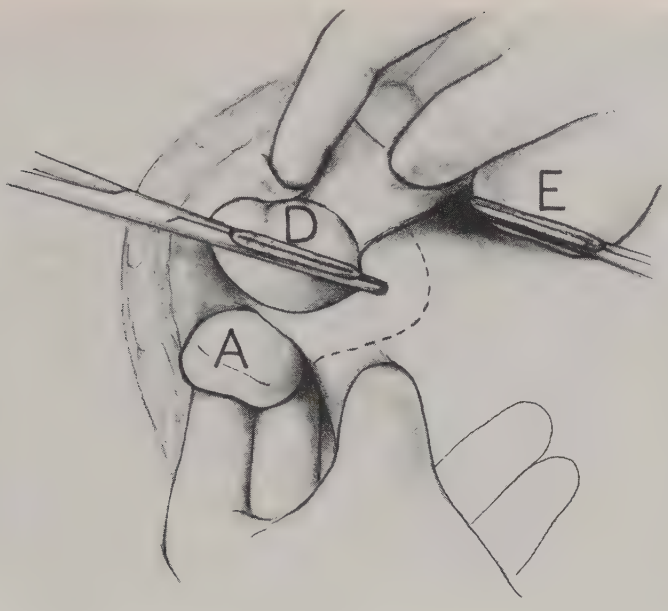

Figure 4. Approximating the efferent limb D to duodenal stump A. E, distal cut end of efferent limb.

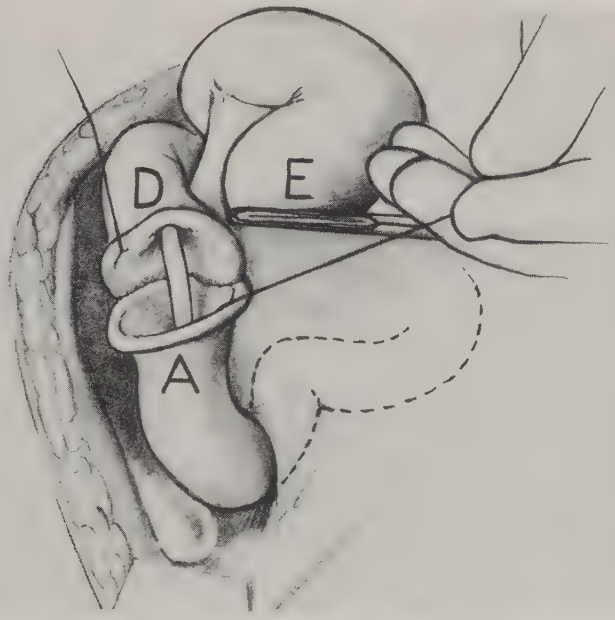

Figure 5. Duodenal stump A open. Posterior layer of anastomosis between efferent limb D and duodenal stump A completed. Long intestinal tube passing through uncompleted jejunoduodenostomy.

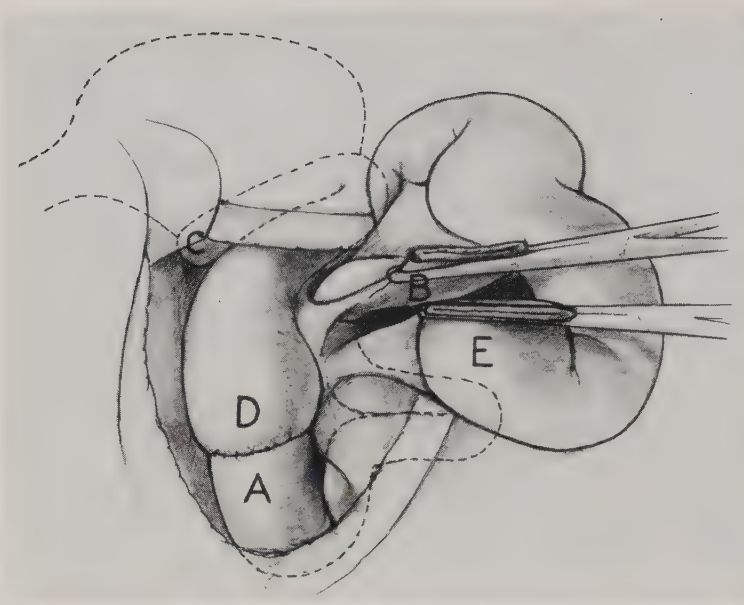

Figure 6. Jejunoduodenostomy completed, D to A. Preparing jejunojejunostomy B to E.

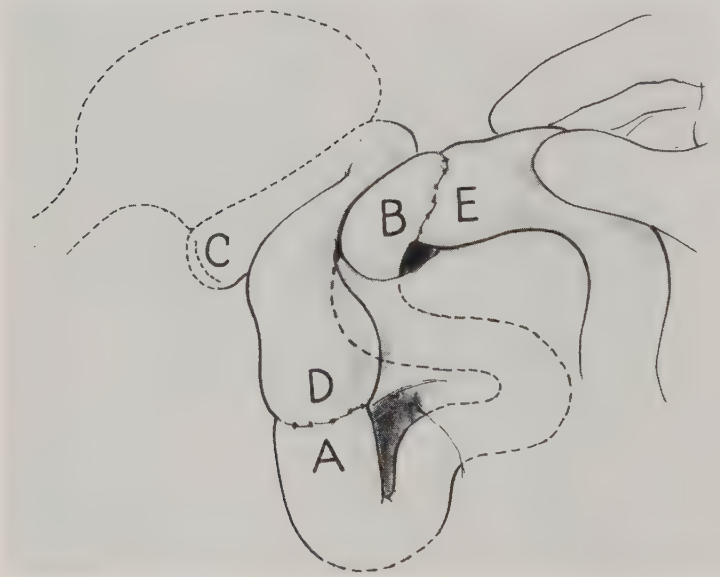

Figure 7. Completed jejunal interposition. C, Closed end of previous afferent limb at lesser curvature of stomach. D-A, Jejunoduodenostomy. B-E, Jejunojejunostomy.

RESULTS OF SURGICAL TREATMENT

Six of the 9 patients had uncomplicated postoperative courses, whereas 3 developed postoperative gastric retention which required an additional period of nasogastric decompression. Of the 9 patients, 8 were classified as having excellent immediate postoperative results, while in one the response was fair. All patients showed marked improvement in regard to appetite and well being. All patients noted a steady slow gain in weight from 5 to 40 pounds during the initial follow-up period of 28 to 48 months. Three to 6 weeks after the surgical procedure, the stool fat excretion had returned to normal in 7 patients. The quantitative bacterial flora count was reduced in all patients (Table 1).

The response of the patient, Case 1, who evidenced a typical kwashiorkor, was dramatic. The patient showed the characteristic discoloration of his hair, skin rash, edema, hypoalbuminemia and steatorrhea. Postoperatively, the patient's hair soon returned from this characteristic red color to its normal black color and the skin rash, edema, and steatorrhea subsided rapidly.

Case 4 developed diarrhea and mild steatorrhea after operation. Culture of material aspirated from the small bowel revealed return of normal flora. He responded rapidly to tetracycline. However, he had another recurrence 2 months later and upper gastrointestinal x-ray at that time showed an outpouching of the residual afferent jejunum proximal to the old gastrojejunostomy. The closed stump and some of the lesser curvature should be resected in this patient.

DISCUSSION

The surgical procedure described in this report is not original with the authors. It was first introduced in 1952 by Henley of England[6] to correct post gastrectomy dumping. Hedenstedt[5] in 1961 reported extensive experience with the use of jejunal interposition for the correction of postgastrectomy dumping. His results were excellent and he has utilized this procedure as a primary one in the treatment of peptic ulcer.

In this operation a segment of jejunum is interposed isoperistaltically between the gastric remnant and the duodenal stump. It is possible to perform this procedure without taking down the original Billroth II anastomosis. It has been shown that the interposed jejunal segment definitely slows gastric emptying and it was hoped that this would alleviate the dumping that so often ensues after a Billroth II anastomosis. However, in Henley's patients there was a high incidence of marginal ulceration at the gastrojejunal anastomosis. Most of them had a high residual acid output. Because of the reported marginal ulceration, the procedure has not been widely used in this country and has not been used specifically for the control of the severe malabsorption seen in some postgastrectomy patients.

Subtotal gastrectomy with and without vagotomy and re-establishment of gastrointestinal continuity either by Billroth I or Billroth II procedures may result in varying degrees of malabsorption and stea-

torrhea. Undoubtedly the majority of patients suffering from this complication have very mild symptoms, many of which subside rapidly with simple medical treatment. Nevertheless, a large majority of these patients fail to regain their preoperative weight. In a small minority, 1 per cent or less, these symptoms may be incapacitating and disabling. The fact that some of the patients may not portray symptoms of an acute nature but of a slowly progressing extent may be the reason that often the true clinical picture is overlooked.

Although definitive etiologic factors have never been identified, it is likely that postgastrectomy malabsorption may have multiple and combining causes. Some of the most commonly considered etiologic factors are the following: the rapid emptying of the gastric stump with inadequate intestinal transit time; inadequate mixing of food with pancreatic enzymes and bile in those patients who had the Billroth procedure in which the duodenum is bypassed and there is not adequate stimulus to the duodenal mucosa and pancreatic enzymes; the development of stasis in the afferent limb, with bacterial action in the afferent limb causing degradation of enzymes and elaboration of toxins; hypovolemia due to hyperosmolarity of jejunal contents; hypoglycemia; hyperserotonemia; and jejunal distention. In all cases of malabsorption due to bacterial overgrowth, symptoms temporarily disappeared when treated with specific antibiotics. This suggests that toxins arising from bacterial metabolism impairing mucosal function may be the true cause of the symptom complex.

Our experience with conversion of Billroth II to Billroth I anastomoses has not been successful in eliminating symptoms of malabsorption and dumping. We have resorted to the Henley procedure and have shown that it successfully corrected stasis and eliminated bacterial overgrowth in our patients (Fig. 8). We have also utilized jejunal interpositions for total gastrectomy in carcinoma of the stomach and for severe dumping syndromes and have been favorably impressed with the nutritional response over a 2½ year period. This will be the subject of a later report.

It is important to keep the interposed jejunal segment short, so as to eliminate recurrence of stasis in the afferent limb. We believe that those among our patients who have had mild recurrence of symptoms had segments more than four inches in length. With the four inch segment which is placed on moderate stretch, excellent results have been obtained. Most impressive has been the striking relief of diarrhea and steatorrhea, and the disappearance of the clinical stigmata of malabsorption.

Studies to interpret the basic correction and the pathophysiology of this entity are warranted. Several factors are probably of importance: adequate stimulation of the pancreas and more effective mixing of food and pancreatic secretions; slower emptying of the gastric stump; and re-establishment of systematic peristaltic action into the duodenum. Cineradiographic studies of our patients in the postoperative period correspond well with those of Hedenstedt[18] which show a sphincter-like mechanism which is normally seen with the intact pylorus. The elimination of stasis in the afferent limb, diminishing bacterial proliferation, directly correlates with medical treatment by antibiotic drugs in these patients.

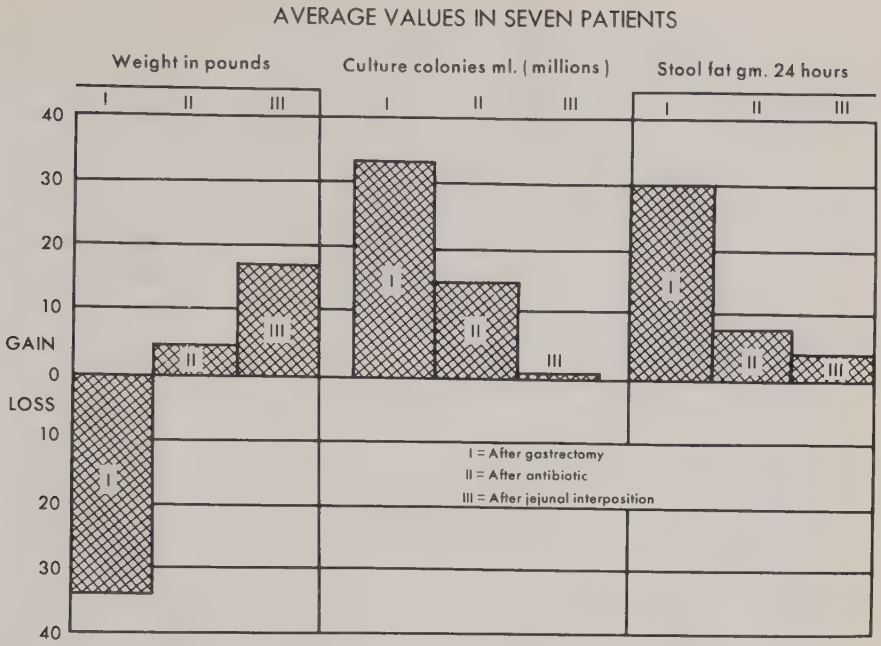

Figure 8. The quantitative bacterial flora count in 7 patients.

SUMMARY

Jejunal interposition for the correction of postgastrectomy steatorrhea was originally performed in 9 patients. Preoperative and postoperative laboratory studies of intestinal absorption and bacterial flora are presented. More detailed review of this subject may be found in the publications of Wirts and Goldstein.[3, 16, 17] The technique and line drawings of the operative procedure are presented. Dramatic improvement was achieved in all manifestations of malabsorption such as cheilosis, glossitis, edema, neurologic defects, discoloration of the hair, profound weight loss, and anemia. This improvement started promptly within 2 weeks of surgery and continued into the postoperative period.

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Complementary Tube Cecostomy

Evaluation of 16 Years Experience with 235 Cases

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In 1962 we reported on our experience with the routine use of a complementary cecostomy in conjunction with resection of the left colon and rectosigmoid.[17] At that time we reviewed 60 consecutive cases of left colon and rectosigmoid resections with complementary cecostomy in which no fistulas or anastomotic leaks occurred and with only one death. We have now had 16 years' experience, which includes 235 consecutive cases, with the procedure and feel strongly that its use should be adopted on every surgical service.

In 1948 Graham[11] found that only 30 per cent of a group of leading general surgeons and proctologists employed surgical decompression when resecting lesions of the left colon and rectosigmoid. In spite of a few recent reports in the literature concerning the use of this simple procedure in which the authors' experience was similar to ours, there is little evidence that its use is widespread. Chaitin,[2] reporting on cecostomy as a prophylactic vent for left colon resection in elderly patients noted one anastomotic leak among 45 patients vented as compared to six anastomotic leaks in 125 resections without cecostomy. King et al.[12] noted only one anastomotic leak and two deaths, unrelated to the cecostomy, in 49 patients in whom prophylactic vent cecostomies were used in conjunction with resections of the left colon or rectosigmoid. Clark and Hubay[3] employed tube cecostomy as a prophylactic vent for distal anastomosis in 97 patients with carcinoma with only two anastomotic leaks and a mortality of 5 per cent. Their experience with cecostomy as a "safety valve" following resection of diverticulitis of the left colon in 27 patients was less satisfactory. Thirty-seven per cent of these patients en-

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countered major complications following surgery such as anastomotic leak (3), cecal fistula (2), wound infection (2), and hepatic failure (1). In each case in which subsequent anastomotic leak occurred, it was noted that an abscess or fistula had been encountered at the time of resection. In this group of patients the mortality rate was 4 per cent. These authors concluded that a complementary tube cecostomy was a valuable procedure with distal resection of neoplastic disease, but less satisfactory after resection for diverticulitis.

The observations of these more recent reports compare favorably with those of Edmiston and Birnbaum[5] who in 1955 compared the results in 67 patients with colon resections and complementary cecostomy with the results in 159 patients with colon resections without cecostomy. There were four deaths in the latter groups due to peritonitis from leakage at the anastomotic site and no deaths due to peritonitis in the former group. In the group without decompression there were three instances of intra-abdominal abscess, three cases with fecal fistulas, and three other patients who required secondary operations because of stenosis of the suture line. In the cecostomy groups there were no cases of peritonitis; however, one instance of pelvic abscess and two fecal fistulas were observed, and five of the cecostomies required secondary closure. The authors concluded that the complications resulting from fecal leakage were more common and more severe when a complementary cecostomy was not performed than when the proximal vent was established. This comparison is more significant when one considers that a cecostomy was usually performed when conditions for primary anastomosis were unfavorable.

Cecostomy was first proposed in 1910 by Litter[1] and although it was popular several decades ago, published reports over the past 25 years have suggested that tube cecostomy was associated with a higher morbidity and mortality than colostomy.[9, 13, 18] McNealy and Landis[14] expressed the opinion that not only are complementary vents unnecessary with the use of continuous suction, but that they also add the burden of possible wound infection or further operation. Rosemond, Burnett, and Cooke[16] analyzed the complications encountered in a series of 83 resections of the colon and concluded that only when trouble develops at the suture line should a proximal vent be established. From reviewing the literature on the subject it is our belief that most of the confusion about the value and safety of cecostomy is due to attempts to lump together its use in acute obstruction from neoplastic disease, inflammatory disease, volvulus, and other causes, with its use as a postoperative vent in elective resections of left colon and rectosigmoid.[7, 15] Catastrophic results from the use of cecostomy in the former groups has no doubt caused many surgeons to abandon the procedure altogether. We propose that our experience with complementary cecostomy clearly demonstrates that it reduces fecal fistulas from anastomotic leaks, abdominal abscesses, peritonitis, general morbidity, and mortality. More recent reports in the literature have shown tube drainage of the cecum to be an effective method of decompressing the colon in many instances. However, none of these seems to emphasize the importance of the routine use of complementary cecostomy in all elective resections of left colon and rectosigmoid.

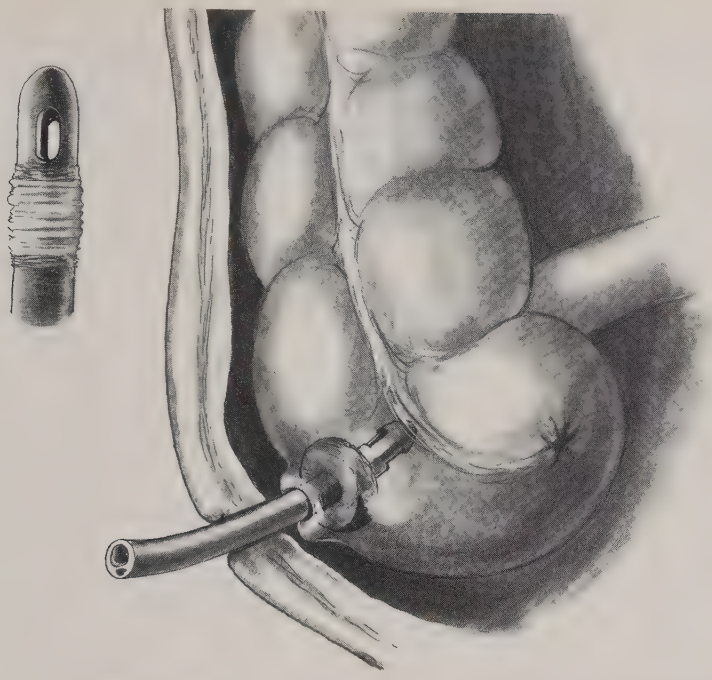

Figure 1. Drawing showing well-inverted cecum around Foley catheter with balloon inflated. Insert shows type of tube.

PROCEDURE

The routine we employ for this procedure has not changed since we first began to employ it 16 years ago, indicating our satisfaction with the procedure and the low incidence of complications from its use. The procedure requires only a few minutes to perform, and effectively decompresses the colon. A Levin tube is placed in the stomach on the day of operation to prevent gastric dilatation. After the primary lesion has been resected and an anastomosis performed, the appendix is removed, if still present. The cecum is exposed and mobilized if necessary and a Dixon cecostomy clamp is applied to the most redundant part. A purse-string suture of 000 catgut is placed and an opening made in the cecum large enough to insert a No. 30 Foley catheter.* The bag is inflated with 5 ml. of water and the purse-string tied. Two additional purse-string sutures of 00 catgut are used to further invert the cecum on the Foley catheter. A good air-tight inversion of the cecostomy tube is essential to avoid early leakage and prevent a fistula from forming after removal of the tube. A small stab wound is made as far lateral as possible in the right lower quadrant of the abdomen, and the cecostomy tube is pulled through the wound. The cecum is held snugly against the anterior abdominal wall and anchored with a single catgut suture (Fig. 1). The cecostomy tube is con-

*C. R. Bard, Inc., Bardix No. 165s

nected to straight drainage and irrigated with 60 ml. of physiologic saline every two hours starting on the second postoperative day. Irrigation and drainage is continued until normal bowel action is established. The cecostomy tube is removed on the tenth to fourteenth postoperative day, depending on the adequacy of bowel action and the absence of intestinal cramps. The Levin tube is usually removed on the first to third postoperative day, depending on the return of intestinal peristalsis.

COMPLICATIONS

There were eleven complications relating to the cecostomy. Two patients developed local subcutaneous emphysema around the cecostomy site which cleared promptly without difficulty with removal of the cecostomy tube. Two patients had local cellulitis and infection at the cecostomy site and these resolved rapidly by removing the tube and applying continuous warm compresses. Three patients had excessive fecal drainage after removal of the cecostomy tube, but in all three drainage ceased spontaneously within 12 days without any treatment. One patient had some excessive bleeding of the cecostomy wound shortly after the operation, and this was easily controlled with a subcutaneous suture of the local bleeding site. There was one patient in the group in whom the cecostomy tube failed to relieve the obstruction at the anastomotic site which was presumably due to edema and ileus. There were no permanent fecal fistulas and all other cecostomy wounds healed in 7 days. None of the patients required a secondary closure of the cecostomy wound.

Since the remaining two complications at least partially contributed to the patients' death, they will be discussed in detail. A 70 year old woman on whom resection for carcinoma of rectosigmoid with complementary cecostomy was performed suffered a myocardial infarction on the ninth postoperative day. She appeared to be convalescing satisfactorily from this complication and the cecostomy tube was removed on the fifteenth postoperative day. Shortly thereafter, the patient complained of considerable right lower quadrant abdominal pain. Approximately six hours after the removal of the tube the patient was explored through a right lower quadrant incision. A localized peritonitis was found but there was no evidence of gross perforation of cecum or separation from the abdominal wall. The cecum was exteriorized and drainage established. Apparently the patient suffered an extension of the myocardial infarction as evidenced by shock, tachycardia, oliguria, and signs of peripheral vascular constriction. In spite of intensive supportive care, she died approximately 48 hours after operation. She was signed out as having died from myocardial infarction and localized peritonitis. No cause was found for the microscopic leakage at the cecostomy site, but presumably was due to the manner in which the tube was removed. The primary cause of death was myocardial infarction but the necessity of having to explore the cecostomy site after a recent infarct certainly contributed to her death.

The only other serious complication and mortality due to the cecostomy occurred in an 83 year old, chronically ill, emaciated (91 lbs.) anemic woman with a partially obstructing carcinoma of the rectosigmoid.

She also had severe emphysema and pulmonary fibrosis, chronic arteriosclerotic heart and kidney disease, and hypoproteinemia. She was considered to be an extremely poor risk. A resection of the lesion with complementary cecostomy was performed on January 7, 1963. Postoperatively she developed chronic congestive heart failure, phlebitis, electrolyte imbalance with azotemia, a myocardial infarct, atelectasis of both lower lobes, and extremely low serum albumin and total protein. Her abdominal wound showed practically no evidence of healing.

On the nineteenth postoperative day she suddenly began to drain a large quantity of serous fluid at the cecostomy site even though the cecostomy tube was still in place. Her abdomen was soft, there was no local tenderness, and she complained of no abdominal pain. However, she continued to deteriorate rapidly and died on the twenty-first postoperative day. Postmortem examination revealed that the patient had acute peritonitis due to leakage at the cecostomy site. The cecum had dropped away from the abdominal wall after the absorption of the sutures and there was no healing reaction between the cecum and the peritoneum. The examination also revealed bilateral hemorrhagic adrenal glands, rheumatic mitral valvulitis with acute bacterial endocarditis, congestive heart failure with bilateral pleural effusion, bilateral lower lobe atelectasis, liver metastasis, and coronary sclerosis and nephrosclerosis. The anastomosis was intact and there was no leakage. It is difficult to see how the outcome of this case could have been different with or without a cecostomy, and the cecostomy did protect the anastomosis for the 3 weeks that the patient lived after operation.

RESULTS

Two hundred and thirty five patients have undergone elective resection of the left colon or rectosigmoid with a complementary cecostomy over the past 16 years. The pathologic lesions, mortality, complications relative to the cecostomy, and absence of anastomotic leakage are shown in Table 1.

Of the 235 patients operated upon, 99 were men and 136 were women. The great majority of these colon and rectosigmoid resections were done for either carcinoma or diverticulitis. There were 116 patients operated upon for carcinoma of the left colon or rectosigmoid with 5 deaths, a mortality of 4.3 per cent. The average age of this group of patients was 66 years.

One male patient, age 54, died on the sixth postoperative day of an acute myocardial infarct. One female patient, age 50, rapidly developed oliguria with physical and laboratory evidence of failing liver and kidney function. An autopsy revealed severe fatty metamorphosis of the liver and tubular necrosis of the kidneys with the collecting tubules containing material usually associated with liver damage. A third patient, a 62 year old female, died on the eighteenth postoperative day of an acute pulmonary embolus. She had shown no evidence of any abdominal difficulty resulting from the operation. The remaining two deaths in this series of 116 patients were analyzed in detail in the preceding section. None of

Table 1. *Results and Complications Following Complementary Cecostomy in 235 Patients*

INDICATIONS FOR RESECTION OF LEFT COLON AND RECTOSIGMOID WITH COMPLEMENTARY CECOSTOMY	NUMBER OF CASES	PER CENT CASES	DEATHS	MORTALITY	COMPLICATIONS RELATING TO CECOSTOMY	MORTALITY, FECAL FISTULAS, ABSCESSES, AND PERITONITIS DUE TO ANASTOMOTIC LEAKS
Carcinoma	116	49%	5	4.3%	5	–
Diverticulitis	85	36.5%	1	1.17%	4	–
Polyps	20	8.5%	1	5%	1	–
Endometriosis	8	3.4%	0	0	1	–
Volvulus	6	2.6%	1	16.6%	0	–
TOTALS	235	100%	8	3.4%	11	0

these five patients who died had any evidence of anastomotic leaks with resulting fecal fistulas, abscesses, or peritonitis. The higher mortality in this group of patients is no doubt due to older average age, the effect of malignant diseases on the nutritional state of the patient, and unavoidable catastrophic complications.

In the group of 85 patients with resection for diverticulitis there was only one death, a mortality of 1.17 per cent. This patient was a 72 year old woman who developed uremia from chronic nephrosclerosis, and later bronchopneumonia and died from these complications. The average age of this group of patients was 60 years. The lower mortality in this group is no doubt due to the lower age and the reduced incidence of serious complications from the effects of malignant disease.

Of the remaining two deaths in the total series one was due to an acute pulmonary embolus in an 81 year old man who had a resection for multiple polyps and the other was due to bronchopneumonia in an 81 year old woman who had a resection of the sigmoid for a chronic volvulus.

None of the eight deaths in this series was caused or influenced by complications resulting from an anastomotic leak. The overall mortality rate of the entire series was 3.4 per cent.

DISCUSSION

After more than 16 years experience with the routine use of the complementary cecostomy in resection of the left colon and rectosigmoid, we are convinced that it is a useful, safe, and desirable procedure and that it should be used in all left colon and rectosigmoid resections. The procedure obviates the trying experience of passing a Miller-Abbott or Cantor tube the day before operation or the excessively long use of nasogastric suction and the potential hazards encountered from the use of these tubes.[6] We believe that our low overall mortality (3.4 per cent) and the extremely low (1.17 per cent) mortality in our diverticulitis series is evidence that left colon and rectosigmoid resections can be done safely if accompanied by a complementary cecostomy. The recent literature, however, provides evidence that questions the presently accepted safety of one stage left colon resections without some type of proximal decompression or venting procedure. Goligher and his colleagues[10] found anastomotic leak in 69 per cent of low anterior resections and 40 per cent of high resections. Botsford and his associates[1] found anastomotic leak to be the major preventable cause of death in a review of 252 patients undergoing both elective and emergency procedures for diverticulitis. Goldstein and Duff carried out a retrospective analysis of 198 patients who underwent elective left colon and rectosigmoid resections between 1960 and 1970. The operative mortality rate from all causes was 6.5 per cent, or 13 patients. Deaths were divided equally amongst those with carcinoma and those with diverticulitis. Five of the 13 deaths were due to sepsis from anastomotic leak. All five deaths occurred in patients who underwent left colon resections without a defunctioning colostomy. In

those patients who underwent resection and colostomy, no deaths were due to anastomotic leak. Death from causes other than sepsis occurred with equal frequency in those patients in both the colostomy and noncolostomy groups. No deaths in this series were associated with closure of the colostomy stoma. Complications such as fecal fistula, peritonitis, septic shock, septicemia, and intra-abdominal abscess were more frequent in the patients who underwent resections without colostomy.

It is evident from our study that the septic complications from anastomotic leak are minimized by the presence of a complementary cecostomy. It is obvious that a proximal colostomy would accomplish the same results, but at the same time would prolong the hospital stay (18 days in Goldstein series), require a second operation for closure of the colostomy, and, generally, is distasteful to both surgeon and patient. It is important to emphasize that a good, careful anastomosis is imperative regardless of the use of either a complementary cecostomy or proximal colostomy, but more so in the former.

SUMMARY

Our experience with the routine use of complementary cecostomy with resection of the left colon and rectosigmoid in 235 patients over 16 years has been reviewed.

The incidence and severity of complications attributable to leakage from the anastomotic line have been largely eliminated since we have used this procedure routinely.

Complications resulting from the use of the cecostomy tube have been minimal with the exception of two cases, and these are presented in detail. There have been no persistent fistulas requiring closure and no herniation at the cecostomy site.

The use of a Foley catheter for the cecostomy is believed to facilitate the construction of the cecostomy, its functions, and eventually its closure.

The low mortality rate (3.4 per cent) (no deaths resulted from sepsis from anastomotic leak) is evidence that the procedure affords protection to the anastomosis.

The extremely low (1.17 per cent) mortality in the diverticulitis series refutes the claim by others that tube cecostomy is unsafe in elective colon resections for inflammatory disease.

Complementary cecostomy is a very useful, safe procedure and should be used routinely in all elective resections of the left colon and rectosigmoid for malignant, benign, and inflammatory disease.

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The Use or Abuse of Antibiotics in Surgery of the Colon

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Although advances continue to be made in the field of colorectal surgery, infection remains a common and potentially serious complication. Most surgeons agree that mechanical cleansing of the bowel is necessary to reduce the morbidity associated with elective colon surgery. Many surgeons also attempt to reduce the intestinal bacteria by administering oral antibiotics in the preoperative period.[6] Although this use of antibiotics is somewhat controversial, the postoperative use of systemic antibiotics is more debatable.[1] The pertinent question is whether postoperative or intra-operative prophylactic systemic antibiotics are effective in reducing the incidence of infection and other postoperative complications, or whether they should be reserved for use only in the treatment of specific infectious complications.

At the Lankenau Hospital, all surgeons routinely use preoperative oral antibiotics and sulfonamides in addition to mechanical cleansing of the bowel in all cases of elective colon surgery. However, in the postoperative period some surgeons avoid while others usually administer systemic antibiotics. The present study is an attempt to analyze the effect of systemic antibiotics on the morbidity following colorectal surgery.

MATERIAL AND METHOD

All colectomies, colotomies, and colostomy closures done at the Lankenau Hospital in the 10 year period from January 1, 1962, to December 31, 1971, were reviewed. Special attention was paid to the complications directly attributable to colonic surgery: wound infection, peritonitis, intra-abdominal abscess, sepsis, enterocolitis, and anastomot-

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ic leak. Complications not directly attributable to colon surgery, such as pulmonary complications, urinary tract infection, myocardial infarction, phlebitis, etc., have been excluded from this study. Complication rates are compared between the treated and the untreated. (Hereafter, "treated" will refer to patients receiving intra-operative or postoperative systemic antibiotics, and "untreated," to those not receiving systemic antibiotics.)

RESULTS

There were 620 patients with a total of 657 operations. Those patients having staged procedures were counted separately for each stage. Procedures involving simple creation of a colostomy without resection were not included. There were 270 men and 350 women, ranging in age from 1 to 90 years, with a mean age of 63.8 years. The distribution of cases over the years is shown in Figure 1, with the age distribution in Figure 2. Final pathologic diagnoses are listed in Table 1; surgical procedures are tabulated in Table 2.

Three hundred and thirty-one patients received preoperative, intraoperative, and/or postoperative systemic antibiotics, while 326 patients did not receive any systemic antibiotics. The complication rates of the two groups are compared in Table 3. Also included are patients with fever of indeterminate cause which reached 101° F for 3 days or more. In many of these cases the cause may have been occult atelectasis, although minor wound or perianastomotic infections and enterocolitis not requiring specific treatment cannot be excluded.

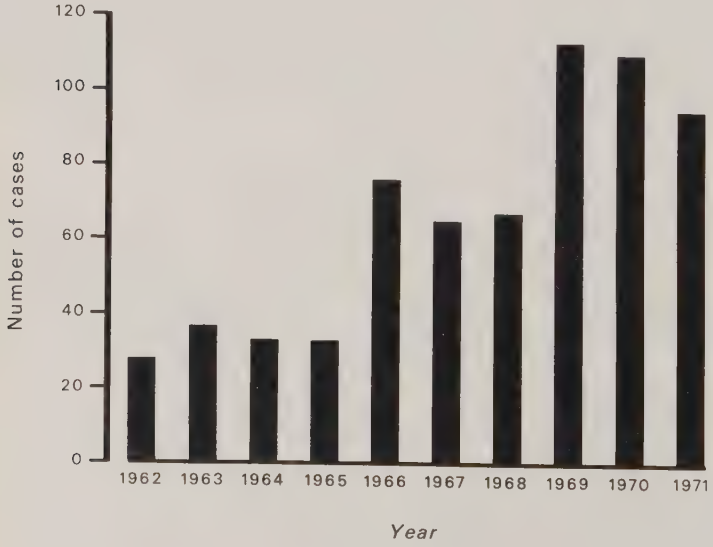

Figure 1. Colorectal surgery performed each year.

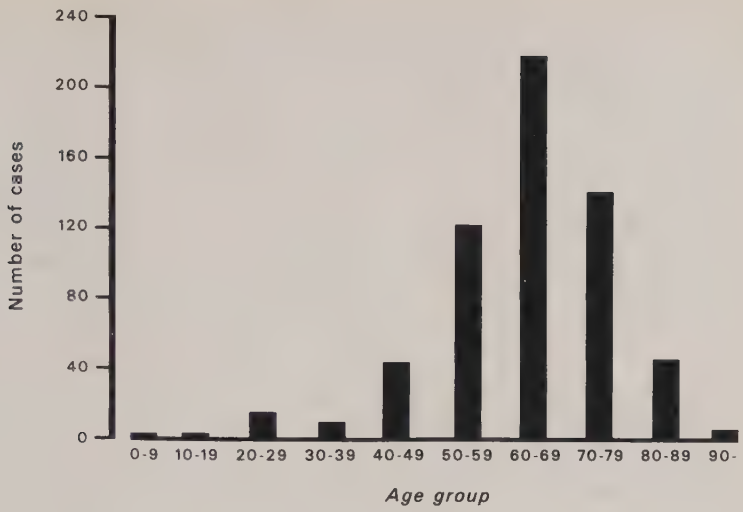

Figure 2. Age distribution of patients undergoing colorectal surgery.

The overall wound infection rate was 8.7 per cent, lower than most reported series.[3, 4, 7-9] The incidence of infection in the "treated" group is significantly higher ($p < 0.05$) than in the "untreated" group. However, the authors believe that these figures are misleading since all colon procedures are tabulated, including those operated upon as emergencies with an unprepared bowel. These grossly contaminated cases are probably more likely to become infected despite antibiotics.

To eliminate this bias, all emergency procedures or those involving obstructed or perforated bowel were excluded. The results are listed in Table 4. Although the infection rate is slightly higher in the "treated" group, the difference is not significant.

In an attempt to further exclude bias from this study, we investigated only those elective cases operated upon by the surgeons who either routinely used or did not routinely use antibiotics. Of the 13 surgeons who performed the surgery in the present series, 6 showed a consistent pattern in their use or non-use of antibiotics. Two routinely used antibiotics and 4 routinely did not, while the others followed no discernible pattern. If patients operated upon by "antibiotic-users" were not treated with systemic antibiotics, these cases were discarded. Similarly, patients operated upon by "non-users" were not included if they received antibiotics for any reason. Table 5 contains the results of this comparison. Here again, although the "treated" group has a slightly higher rate of infection, the difference is not statistically significant.

The mortality as well as complications other than wound infection are quite comparable in the "treated" and "untreated" groups. None of the differences is statistically significant, as can be seen in Tables 3 through 5.

Table 1. *Diagnoses*

Carcinoma of colon and rectum	392
Polyps of colon	87
Diverticulitis	82
Crohn's disease	14
Ulcerative colitis	12
Bleeding diverticuli	5
Miscellaneous	28
Total	620

Table 2. *Operations*

Sigmoid resection	187
Right colectomy	173
Colotomy and polypectomy	79
Anterior resection, rectum	59
Left colectomy	53
Closure, colostomy	44
Transverse colon resection	25
Abdominal perineal resection	17
Total coloproctectomy	14
Miscellaneous	6
Total	657

Table 3. *Complications Directly Attributable to Colonic Surgery, All Cases*

	"TREATED"	"UNTREATED"	TOTAL	
Wound infection	37(11.2%)	20(6.1%)	57(8.7%)	$p < 0.05$
Anastomotic leak	18(5.4%)	10(3.1%)	28(4.3%)	$p < 0.05$
Pseudomembranous enterocolitis	1	1	2	
Fever 101° F 3 days	49(14.7%)	43(13.2%)	92(14.0%)	p 0.05
Death	20(6.0%)	19(5.9%)	39(6.0%)	p 0.05
Number of operations	331	326	657	

DISCUSSION

There are theoretical disadvantages in the use of antibiotics as a prophylactic measure for patients undergoing surgery upon the colon. First, they may encourage overgrowth of resistant bacteria or fungi. Second, they may mask the severity of infection by temporarily suppressing growth of bacteria, and thus delay the proper treatment. Certainly, antibiotics cannot be relied upon to replace meticulous surgical technique. On the other hand, if effective antibiotics are used before bacteria can colonize and become established, it might be possible to suppress or even abort an infection.

Table 4. *Complications Directly Attributable to Colonic Surgery, Elective Cases*

	"TREATED"	"UNTREATED"	TOTAL	
Wound infection	27(9.9%)	19(6.1%)	46(7.9%)	p 0.05
Anastomotic leak	8(2.9%)	8(2.6%)	16(2.7%)	p 0.05
Pseudomembranous enterocolitis	1	1	2	
Fever 101° F 3 days	45(16.5%)	36(11.5%)	81(13.9%)	p 0.05
Death	7(2.6%)	11(3.5%)	18(3.1%)	p 0.05
Number of operations	272	311	583	

In this study, the most commonly used antibiotics were penicillin and streptomycin in combination or sodium cephalothin for 5 to 7 days starting the night before surgery or immediately after surgery. Among the 27 patients with wound infections in elective cases on whom systemic antibiotics were used, 23 had a complete culture and sensitivity report as shown in Table 6. It is noteworthy that the majority of wound infections were due to resistant organisms. Until more effective antibiotics are discovered, the problem of drug resistance will persist. There were 4 patients in whom sensitive organisms were cultured from the pus despite effective antibiotics. In all four, antibiotics had been started postoperatively. If antibiotic therapy is initiated after bacteria have begun to colonize and form abscesses, such treatment will not be effective. If antibiotics are used, it is theoretically more advantageous to start them before or during the operative procedure. In the 4 patients on whom systemic anti-

Table 5. *Complications Directly Attributable to Colonic Surgery, Surgeons Following Usual Routine of Use or Non-Use of Antibiotics*

	"TREATED"	"UNTREATED"	TOTAL	
Wound infection	16(8.6%)	7(5.0%)	23(7.1%)	p 0.05
Anastomotic leak	7(3.8%)	5(3.6%)	12(3.7%)	p 0.05
Fever 101° F 3 days	42(22.8%)	23(16.5%)	65(20.0%)	p 0.05
Death	6(3.2%)	6(4.3%)	12(3.7%)	p 0.05
Number of operations	185	139	324	

Table 6. *Culture and Sensitivity Results of Wound Abscesses in the Elective "Treated" Group*

ANTIBIOTICS STARTED		NO GROWTH	SENSITIVE	RESISTANT	ONE ORGANISM SENSITIVE, THE OTHER NOT
Preoperative	4	1	0	3	0
Postoperative	19	3	4	1	11

biotics were started before the operative procedure, none developed wound infection due to sensitive organisms; 3 cultured resistant bacteria and 1 had a sterile abscess.

A word should be mentioned about postoperative enterocolitis, the reported incidence of which was as high as 30 per cent.[2, 5] In this study, there were occasional patients who developed diarrhea with or without fever in the postoperative period. Most cases subsided spontaneously without specific treatment. Only 2 patients developed full blown pseudomembranous enterocolitis. Both occurred in the early part of this study when neomycin was given for 2 to 3 days preoperatively.

A review of the literature shows that infectious complications following colorectal surgery occur frequently. The incidence reported in recent years is up to 30 per cent.[8] Systemic antibiotics have been claimed to decrease the infection rate from 30 to 7.4 per cent.[8] On the other hand, they have been incriminated in raising the infection rate.[2] The present study suggests that systemic antibiotics neither decrease nor increase the rate of wound infection following colorectal surgery. We agree with Hafner[4] that at this stage one should keep an open mind in the use of systemic antibiotics. If one chooses to use systemic antibiotics, they should be given before the start of the operation so that effective blood levels are attained at the time of maximal contamination.

SUMMARY AND CONCLUSION

All transabdominal colorectal surgery performed at the Lankenau Hospital in the past decade was reviewed in an attempt to evaluate the effect of systemic prophylactic antibiotics on the incidence of infectious complications. All elective operations were performed after 2 to 3 days of mechanical cleansing of the bowel as well as administration of oral antibiotics. Approximately half of the cases received systemic antibiotics in the peri-operative period while the other half did not. No significant difference in infection rate was found. It is concluded that systemic antibiotics as available today are probably not effective enough to decrease the infectious complications following colorectal surgery.

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The Handling of Contaminated Abdominal Wounds

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Wound complications following emergency and elective procedures on the gastrointestinal and biliary tracts continue to represent a major source of postoperative morbidity for the patient and a distressing area of concern for the surgeon. Mendoza et al.[6] reported a wound infection rate of 20 per cent for abdominal cancer surgery at Roswell Park Memorial Institute. Alexander and Prudden[2] stated that the overall wound infection rate at Presbyterian Hospital in New York was 4.2 per cent. This latter figure, of course, included a much wider range of procedures than those being considered here, and it would be much higher if just gastrointestinal and biliary cases were tabulated. Grosfeld and Solit[4] reported a 34 per cent wound infection rate in cases of perforated appendicitis in which the skin was closed. In analyzing 200 wound disruptions Alexander and Prudden[2] found that 14 per cent of them were infected and another 17 per cent had been associated with hematomas. In younger patients both of these figures were higher and they concluded that "it seems highly probable that technical and therefore preventable factors were responsible for most of the wound disasters in these young patients."

Various approaches have been used in an attempt to cut down on the incidence of wound infections. Herter[5] summarized concisely the pros and cons of mechanical and antibiotic preparation of the bowel for surgery and reported a 13 per cent wound infection rate despite these measures. Topical antibiotics have been reported to markedly decrease the incidence of wound infection in colorectal surgery,[3] and the use of

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Table 1. *Wound Complications Following Gastrointestinal Surgery. April 1970 to April 1972*

OPERATION	TOTAL	WOUND ABSCESS	WOUND SINUS	DEHISCENCE
Gastric procedure	42	0	0	1
Small bowel resection	34	0	0	0
Colon resection	80	0	0	0
Biliary tract procedure*	259	6**	3	0

*20 per cent positive cultures; 75 procedures on common bile duct.

**All had primary closure of skin.

Organisms involved: E. coli, 6; Klebsiella, 5; alpha-streptococcus, 3; coagulase-positive staphylococcus, 2; Proteus, 1; Pseudomonas, 1.

monofilament suture material[1] has previously been reported to be superior to multifilament material. In addition, the surgical experiences of military surgeons in Southeast Asia have made it clear that primary skin closure may be quite detrimental to wound healing and the practice of so-called delayed primary closure has become an accepted part of total patient care for the gravely wounded soldier.

During the past 2 years we have used a highly successful method for handling grossly contaminated and potentially contaminated wounds. It consists of leaving the skin and subcutaneous tissue planes open after fascial closure is accomplished with nonabsorbable monofilament polypropylene. Delayed primary skin closure is subsequently performed with paper adhesive tape strips. Our two-year experience is summarized in Table 1 and will be discussed in detail along with the actual mechanics of the technique.

In general, all procedures on the biliary tract were performed through a transverse right upper quadrant incision with complete division of the right rectus muscle and linea alba. Similarly, gastric operations were done through midline epigastric incisions; colon and small bowel resections were accomplished through vertical rectus muscle-splitting incisions. In most biliary cases the peritoneum and posterior rectus fascia were closed with running doubled 2–0 chromic catgut. The 0-polypropylene was used on the anterior rectus fascia and linea alba, and placed as interrupted vertical figure-of-eight sutures. The vertical rectus muscle-splitting incisions were closed in a similar manner or, in equal numbers, in one layer using the polypropylene only. All midline incisions were closed in one layer with vertical interrupted figure-of-eight 0-polypropylene sutures. We use chromic catgut sutures routinely to approximate the oblique muscles of the abdominal wall, and therefore have not included appendectomies in this series. However, the authors emphasize that the same principal of delayed primary wound closure has been followed for purulent, necrotizing, and perforated appendicitis with a thoroughly gratifying decrease in wound morbidity.

The handling characteristics of the polypropylene need mention. The material is strong and durable, but very slippery. Knot tying is best ac-

complished with the needle holder rather than by hand. The first throw should be a surgeon's knot and, on occasion, may actually require three loops to hold. A total of four or five square knot throws are required and the ends should then be cut flush with the knot. The lack of interstices in the polypropylene more than makes up for any minor difficulties encountered when first learning to handle the material.

The skin and subcutaneous tissue were routinely left open in this series. The only exception was for elective biliary tract surgery grossly free of infection. These cases were closed primarily at surgery. All other wounds were kept open by lining the subcutaneous cavity with porous nonadherent gauze and then filling the defect with providine soaked gauze. All this was covered by a standard dry dressing and held in place by Montgomery straps. The eventual closure of all wounds depended upon the degree of purulent discharge and was accomplished anywhere between 5 and 21 days after operation. Most wounds were readily closed with paper adhesive strips and usually by the seventh postoperative day. On a very rare occasion suture closure under local anesthesia was required because of extreme subcutaneous obesity, which prevented accurate apposition of the wound. Occasionally the paper strips had to be removed because of lingering wound discharge and then reapplied after further local care. Using this method of delayed primary closure, the incidence of wound abscess, cellulitis and patient discomfort not only approached but actually reached zero. The nursing care required, of course, was increased but this was really very little and when measured against the problems of caring for a patient in isolation was, in fact, considered much easier and infinitely more rewarding by all concerned. It must be pointed out that appreciation of the technique by the nursing service was not learned without several episodes of emotional stress caused by initial, unaccompanied inspection of open wounds which were immediately reported as having "dehisced."

The technique, as described, has been used whether the surgery was elective or emergency, and whether or not time permitted adequate preparation of the gastrointestinal tract. Our routine preparation for colon work includes mechanical cleansing regime and 48 hours of oral kanamycin. In addition, parenteral antibiotics are given, and we have been unable to find anything superior to the old "triple therapy" consisting of penicillin, streptomycin, and tetracycline. Preoperative antibiotic "loads" were always used before proceeding with perforated ulcers, obstructing cholangitis, empyema of the gallbladder, emergency right colon lesions and left colon perforated diverticular or complicated malignant disease. Intraperitoneal drains have been used liberally and usually have been brought out through separate stab wounds. Sump drains have been used in the pelvis frequently, particularly with low anterior anastomoses.

In addition to the lack of wound abscess formation fostered by this method, there has been a marked decrease in two other infrequent, but not rare, wound complications, namely suture sinuses and wound disruptions. Polypropylene is a monofilament material and, lacking interstices, fails to harbor and support microaggregates of bacteria and their necrotic tissue pablum. In our entire 2 year experience we have had to "fish out"

only 3 polypropylene sutures from indolent sinus tracts and, even better, our experience with wound disruption has dwindled to just one, a vertical midline epigastric incision used for a perforated gastric ulcer in an elderly debilitated man.

COMMENT AND CONCLUSIONS

The routine immediate closure of the skin and subcutaneous tissue in abdominal surgery does not add any positive aspect to firm wound healing and, in fact, favors the introduction of several disruptive forces. The open wound is easily cared for and inspected daily and delayed closure carried out without discomfort or inconvenience at the bedside at such time as conditions permit. The scars resulting from delayed primary closure are invariably fine lines and are free of lingering subcutaneous induration. The patient's wound complaints during the outpatient postoperative follow-up period have been almost nil and the scars have all matured normally and proved stable.

Not one wound incision and drainage has been required for incisions closed in this delayed primary manner. The wound abscesses following biliary tract surgery all occurred in cases closed primarily at surgery and were subsequently found to have a positive bile culture, which we take routinely in the operating room. Grossly infected biliary cases have all been left open and complete satisfaction again has resulted.

The monofilament polypropylene suture is stout, durable and causes no inflammatory tissue reaction. The mass closure technique with interrupted figure-of-eight sutures has proved most satisfactory. We are in complete agreement with Alexander and Prudden[2] who noted that the most common error in fascial closure is the inclusion of too little, rather than too much, tissue.

SUMMARY

Using the technique of delayed primary closure of the skin and subcutaneous planes, Grosfeld and Solit[1] reported a drop in the wound infection rate from 34 per cent to 2.3 per cent in cases of perforated appendicitis. In the past 2 years this method has been used in over 200 surgical procedures on the biliary and abdominal portion of the gastrointestinal tracts. Wound hematomas and infections requiring incisions and drainage have virtually disappeared using this method, and the fascial closures accomplished with polypropylene have proved to be durable and almost completely trouble free as regards sinus formation and wound disruption. Our trend has been one of continual liberalization of the indications for using this technique and we have come to use it if there is the slightest possibility of bacterial contamination.

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Rationale for Selection and Sequence of Diagnostic Surgical Procedures in Pulmonary Disease

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Complete evaluation of the patient with a roentgenographic abnormality of the lung includes documentation of the etiology to permit accurate prognostication and institution of therapy based on sound judgment. Patient morbidity can be minimized and diagnostic efficiency enhanced by a logical choice of procedures applied in an effective sequence. The purpose of this presentation is to suggest a practical guide for selecting appropriate procedures which has evolved through years of experience in the management of patients with a variety of pulmonary diseases.

A diagnostic surgical procedure is arbitrarily defined as an invasive examination or manipulation which has the potential for acquiring representative pathologic tissue. It is assumed that smear and culture of sputum specimens, special chest roentgenograms, skin tests, serologic tests, and angiograms will have been done when indicated. Also, it is expected that all extrathoracic procedures of diagnostic importance will have been accomplished.

DIAGNOSTIC PROCEDURES

Bronchoscopy

Bronchoscopic examinations can be conducted in all but a very few patients either awake using topical analgesia, or asleep after the adminis-

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tration of a general anesthetic agent. Vocal cord mobility and appearance are noted as the bronchoscope is introduced into the trachea. Inspection of the visible tracheobronchial tree will disclose distortion or fixation of the carina, inflammation of the bronchial mucosa, the character and source of secretions or blood, centrally located endobronchial tumors, and lymph node erosion into a bronchus. The extent of visual inspection can be enhanced by introducing either an angled telescope or a fiberoptic lens system. This direct approach to endobronchial pathology affords access to tissue via biopsy or washing.

More distal pulmonary parenchymal lesions are now approachable through the tracheobronchial tree as a result of a recently developed technique.[1] The manipulation of a catheter into a bronchus supplying an area of diseased lung permits extrusion of a small brush into the lesion with recovery of tissue for histologic study. Using these endobronchial techniques a diagnosis may be established in 80 per cent or more of patients with bronchial tumors and parenchymal pneumonia or destructive lesions involving a segment or more of lung.[10]

Pleural Biopsy

The presence of pleural fluid and/or pleural thickening may provide access to diagnostic tissue or permit isolation of bacteria. Percutaneous needle biopsy of the pleura is usually reserved for the patients with demonstrable pleural fluid. This precaution serves to protect the underlying lung from laceration by the biopsy needle as it is introduced into the pleural space. Upon completion of the pleural biopsy procedure the remaining pleural fluid is aspirated and forwarded to the laboratory for bacteriologic and cytologic study. Although the positive diagnostic yield from this procedure is not impressively high, it is simple, direct, well tolerated and associated with minimal risk.

Open pleural biopsy by limited thoracotomy and surgical exploration should be considered when the potential findings may alter the subsequent management of the patient significantly. If the needle biopsy of the pleura is interpreted as nonspecific inflammatory reaction, this should be accepted with skepticism and thoracotomy recommended. This philosophy increases the probability of diagnostic specificity with an acceptable risk and morbidity.

Lymph Node Biopsy

Lymph nodes are accessible for surgical biopsy at several sites along established anatomic lymph draining channels from the lung. These lymph node bearing sites are peribronchial, subcarinal, paratracheal, scalene, and supraclavicular. Two general observations are supported by clinical evidence: (1) a palpable supraclavicular lymph node will very likely reflect the nature of any existing pulmonary disease, and (2) the closer to the lung the biopsy is made, the greater is the likelihood of obtaining representative pathologic tissue. Daniels[3] demonstrated that excisional biopsy of the node-bearing scalene fat pad frequently provided a histologic diagnosis for patients with pulmonary disease. This became a particularly popular procedure for judging operability in patients with bronchogenic carcinoma and for obtaining tissue confirmation of sar-

coidosis in patients with characteristic clinical findings. Staged bilateral scalene fat pad excisions previously employed in selected patients are rarely considered today. Subsequently Harken et al.[5] described cervicomediastinal exploration and paratracheal lymph node biopsy with an increased yield of pathologic tissue.

Radnor[9] suggested superior mediastinal exploration from the neck and Carlens[2] designed a mediastinoscope to approach the subcarinal and peribronchial lymph node bearing areas in the chest. Surgeons who object to the limited exposure afforded through the mediastinoscope have used parasternal mediastinotomy with comparable effectiveness. In so doing they accept the associated increased postoperative discomfort.[7]

The site elected for the biopsy is determined by the presence or absence of palpable supraclavicular lymph nodes. Excision of the scalene fat pad has been abandoned, with rare exceptions, in favor of more productive procedures. The surgical approach to mediastinal lymph node bearing areas, that is, the paratracheal and hilar lymph nodes, is determined by the surgeon's preference. In this clinic mediastinoscopy, or occasionally mediastinotomy, is used in selected patients with suspected carcinoma of the lung, mediastinal lymphoma or sarcoidosis. In addition patients thought to have tuberculosis, histoplasmosis or coccidioidomycosis are considered candidates for mediastinoscopy when roentgenographic evidence of hilar or paratracheal lymph node enlargement is present.

Lung Biopsy

The ultimate source of representative pathologic tissue in patients with undiagnosed pulmonary disease is the lung. The precise etiology of a multitude of pulmonary diseases is not specifically reflected in pathologic changes elsewhere, nor is a characteristic material produced that can be recovered by endobronchial aspiration. A few such examples are pulmonary fibrosis, histiocytosis, eosinophilic granuloma, and diffuse interstitial pneumonitis. In addition some focal pulmonary lesions require direct biopsy for diagnostic confirmation.

Percutaneous needle biopsy is being used with increased frequency. Postbiopsy pneumothorax of varying severity and bleeding is accepted in 30 to 60 per cent of all patients in lieu of thoracotomy.[8] However, one must also be prepared for the probability that representative tissue will not be recovered; nor will there be a definitive pathologic diagnosis in every instance of attempted biopsy. A theoretical consideration, frequently discussed but difficult to document, is the probability of seeding a needle tract with malignant cells after biopsy of a pulmonary neoplasm. The inclination of authors is to reserve percutaneous needle biopsy of the lung for patients who are considered to be inoperable for one reason or another.

Thoracotomy with exploration and lung biopsy is the diagnostic court of last resort for patients with pulmonary diseases. This may be accomplished through a limited anterolateral intercostal incision with a sampling of a representative portion of the lung by wedge excision, as proposed by Klassen et al.[6] Alternatively, a more adequate posterolateral thoracotomy may be appropriate for excision of a focal lesion. In addition to the histologic study, cultures are made from the lung tissue.

PULMONARY PROBLEMS

The sequence with which the diagnostic surgical procedures are employed in a specific patient is determined by the disease probabilities discerned from the clinical manifestations. It is illogical to subject every patient with a pulmonary disease to bronchoscopy followed by lymph node biopsy and subsequent thoracotomy, just as it is unreasonable to deny endoscopy for patients with bronchial obstruction in favor of exploratory thoracotomy.

Diffuse Pulmonary Diseases

Included in this classification are those entities which produce multiple granulomata or diffuse infiltrates. In the majority of such cases the pathology is confined to the lung parenchyma. Therefore it is appropriate to consider a limited thoracic exploration and lung biopsy as the most direct and productive procedure. One exception to this general statement would be the patient suspected of having sarcoidosis. Mediastinoscopy is considered to be the primary diagnostic surgical procedure for confirming the presence of non-caseating granulomata. This includes patients without roentgenographic hilar enlargement. Patients with diffuse pulmonary infiltrates may benefit diagnostically from bronchoscopy particularly if an area can be identified well enough to pass a bronchial brush into the pathologic lung. If the etiology is not established, lung biopsy should be considered.

Pulmonary fibrosis cannot be proved except by a microscopic examination of a representative section of the lung. Admittedly, percutaneous needle biopsy of the lung, if technically successful, may disclose the pathology in this group of patients. However the practice in this clinic is to recommend an open surgical biopsy. It is important to establish a diagnosis so that treatable pulmonary disease may be recognized early and specific therapy initiated when indicated.

Focal Pulmonary Lesions

Diagnostic interest in focal pulmonary lesions has a more direct relationship to therapy. Peripheral solitary lung nodules are best approached via thoracotomy and excised for histologic diagnosis. The excision biopsy becomes therapeutic for benign nodules. A more adequate lung exeresis is accomplished for neoplastic lesions. Bronchoscopy is recommended as the initial procedure for patients with pulmonary masses, focal nonresolving pneumonic lesions, and cavitations of the lung. These roentgenographic abnormalities are frequently associated with partially obstructing endobronchial tumors which may be biopsied endoscopically. In addition it is highly probable that the brush biopsy will provide positive information in these circumstances.

Lymph node biopsy is practiced in selected patients suspected of having bronchogenic carcinoma. As previously stated, palpable supraclavicular lymph nodes are excised to judge operability. The mediastinal nodes are biopsied in patients with roentgenographic evidence of paratracheal or hilar node enlargement or in those individuals in whom thoracotomy may be associated with a high risk of mortality.

Percutaneous needle biopsy of suspected malignant lung lesions is generally reserved for nonresectable tumors where radiation or chemotherapy is under consideration. Excisional biopsy at formal thoracotomy is preferred where feasible. Cystic lesions of the lung necessitate thoracotomy for evaluation and surgical treatment.

Pleural Effusion

It is important that the cause of persistent or recurring pleural effusion with pleural thickening be established, since therapy for tuberculosis pleuritis is curative and the implications of primary or secondary neoplasm must be considered with regard to palliation. The usual practice is to obtain a needle biopsy of the pleura at a time when pleural fluid is present to avoid trauma to the lung. The probability of recovering specific pathologic tissue in the small piece of pleura obtained by this method is not high. However, it is readily done and, if diagnostic, eliminates the necessity for proceeding with open pleural biopsy. In those cases where a surgical approach is made to obtain a pleural specimen it is advisable to have a sufficiently large incision to insure acquisition of a representative sample of tissue.

SUMMARY

The diagnostic surgical procedures commonly used to ascertain the nature of a pulmonary disease have been discussed, emphasizing rational selection and logical sequential application in clinical practice. Bronchoscopy with endobronchial biopsy, pleural aspiration and pleural biopsy, lymph node biopsy, and lung biopsy have been considered. Logical combinations of procedures have been suggested for application in specific circumstances related to clinical manifestations of pulmonary diseases.

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Management of the Post Pneumonectomy Pleural Space

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Although almost 40 years have elapsed since the first successful human pneumonectomy, controversy over the proper management of the residual pleural space continues. Early data seemed to support the view that mediastinal displacement from the midline to the side of operation is accompanied by undesirable changes in hemodynamics and ventilation. The cough mechanism was thought to be less efficient. Distention of the remaining lung was suspected of causing pulmonary emphysema. Our clinical and laboratory experience leads us to believe that mediastinal displacement to the side of operation is not harmful and indeed, may be beneficial in certain respects. It is the purpose of this communication to review the subject, presenting evidence to support our beliefs.

CLINICAL EXPERIENCE

In the early 1950's the majority of our pulmonary resections were performed for tuberculosis. Since pleural empyema was an ever-present threat, early obliteration of the pleural space was a necessity. Thoracoplasty was effective, but resulted in decreased pulmonary function.[10] We, therefore, explored the possibility of filling the pleural cavity by encouraging early expansion of the remaining lung after partial resection, by relatively strong suction, even at the risk of producing distention of an abnormal degree.[14] We soon determined that overinflation in patients treated with antituberculous drugs did not adversely affect his tuberculosis, or ventilatory function, even when considerable mediastinal displacement occurred.[15] This encouraged us to apply the same principles to total pneumonectomy.[16]

At the completion of the pneumonectomy we leave two intercostal

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drainage tubes in the pleural cavity, one to the apex and the other to the base posteriorly. This tends to prevent clotted hemothorax which might interfere with mobility of the mediastinum and diaphragm. Immediately after operation, the tubes are connected either to balanced drainage[13] or to controlled suction. The former offers the advantage of permitting small bronchial stump leaks to heal while it is used. The mean pleural pressure is adjusted to effect a moderate displacement of the mediastinum to the side of operation. The blood pressure, pulse, respiration, and electrocardiogram are monitored. Drainage is terminated when the volume per 24 hours falls below 200 ml.

Since adopting this method of treating the post pneumonectomy pleural space, we have utilized it in 86 unselected patients. We have not noticed any ill effects upon peripheral arterial blood pressure, pulse rate, respirations, or electrocardiogram. This is in agreement with the experience of others.[19] Where central venous pressures were determined, we have noticed no increase with displacement of the mediastinum to the side of operation. The cough mechanism appears unaffected. Subjectively, many patients seem to breathe better when the remaining lung is distended. When empyemas developed, they were comparatively small as the pleural space was minimal in size.

One patient developed wheezing immediately after operation. Radiographs revealed scattered infiltrations suggestive of pulmonary edema. Although several reports of pulmonary edema following rapid expansion of a lung appear in the literature,[7, 21] we do not believe that this was the diagnosis in this patient, as the signs did not improve with empirical treatment for pulmonary edema.

Numerous reports[2, 9] and our own experience indicate that pulmonary distention cannot be shown to cause or aggravate pulmonary emphysema.

LABORATORY EXPERIENCE

Arguments against permitting mediastinal displacement to the side of operation are based principally upon the results of laboratory studies. The most important results can be summarized as follows.

Vascular Resistance

Following pneumonectomy, vascular resistance need not increase with distention of the remaining lung.[4, 17] Although blood flow is approximately double the preoperative level, pulmonary arterial pressure at rest is frequently normal.[8]* New vascular channels have been recruited and a sufficient number are available to accommodate a considerable increase in flow. When blood flow is increased further by exercise, the limits of capacity are reached and the pulmonary arterial pressure may rise slightly.

Pulmonary vascular resistance is influenced by the state of inflation of the lung, tending to be high at deflation and extreme inflation and least

*Resistance = $\frac{\text{pressure}}{\text{flow}}$

at 50 per cent inflation.[20, 22] Almost all postpneumonectomy patients eventually develop pulmonary hyperinflation. Yet, there is no evidence that the incidence of pulmonary arterial hypertension and increased vascular resistance is significantly higher with such degrees of inflation than in those patients who have had mediastinal stabilization procedures such as thoracoplasty. Furthermore, it has been shown that life expectancy is similar whether or not overdistention of the remaining lung is prevented by plombage.[6]

Ventilation-Perfusion

Distention of the remaining undiseased lung following pneumonectomy is not accompanied by uneven distribution of gases.[8] Distribution of blood may be improved as new vascular channels are recruited. Reported improved diffusing capacity in distended lungs probably indicates an increased perfused alveolar surface area. As might be expected, resting post pneumonectomy arterial Po_2 is within normal limits.[2]

Work of Breathing

Theoretically, removal of approximately half the conducting airways should double airway resistance. However, this is partially neutralized by the effects of pulmonary distention upon airways. Although bronchi are lengthened as well as dilated, the net result is a reduction of airway resistance,[3, 11] which tends to offset the effects of removal of some of the conducting airways. We have found that in some post pneumonectomy patients with distended lungs, airway resistance actually becomes less than with two lungs preoperatively.[18]

Some investigators have shown that pulmonary compliance decreases with distention following pneumonectomy. The calculated work of breathing is thereby increased.[12] Analysis of published information fails to indicate that this calculated increase in work is significant.[9] Furthermore, if oxygen consumption at rest may be used as an indication of the amount of work being done, it cannot be shown that postpneumonectomy pulmonary distention leads to a significant increase in the amount of work.[4]

DISCUSSION

Distention of the remaining lung afer pneumonectomy is accompanied by physiologic changes, some of which are theoretically beneficial and others not. Hyperinflation may lead to increased vascular resistance, decreased pulmonary compliance, and increased work of breathing. However, accumulated evidence indicates that the magnitude of these adverse changes is not enough to be clinically significant. On the other hand, hyperinflation reduces airway resistance. Ventilation-perfusion relationships are essentially unchanged.

Disability following pneumonectomy appears to be related more to the health of the remaining lung than to the state of inflation. If the remaining lung is relatively free of disease it will tolerate a considerable amount of distention without significant changes in resting vascular resistance, compliance and work of breathing. Even when cardiac output

and ventilation are increased with exercise it cannot be shown that the distended lung behaves significantly less well than the undistended lung.

Few now believe that distention causes or aggravates emphysema. Pulmonary emphysema is often present before pneumonectomy and we have noted progression in a lung collapsed by thoracoplasty.

SUMMARY

Displacement of the mediastinum to the side of operation with consequent hyperinflation of the remaining lung offers more advantages than disadvantages. Objections are based upon the results of physiologic studies which do not appear to be clinically significant.

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Treatment of Thermal Injuries

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The Burn Service at the Thomas Jefferson University Hospital has evolved from the enthusiastic interest of medical and ancillary services with special skills in treatment of thermal injuries.

The purpose of this paper is to report on the author's personal involvement in the integration of the accident ward, intensive care unit, physical therapy facilities, and separate accommodations for the delivery of specialized care to severely burned patients.

INITIAL CARE AT THE ACCIDENT WARD

Care of the patient with a major thermal injury is initiated upon arrival at the accident ward where he is placed in a special burn cubicle. All personnel dealing with the patient are attired with caps and masks and sterile gowns and gloves.

Resuscitation

INHALATION INJURY. Since inhalation injury may rapidly affect respiratory function, resuscitation maneuvers begin by checking the adequacy of the airway. Restlessness, irrational behavior, prolonged respiratory expiration, cyanosis, and cough foretell damage to the respiratory tract. Careful search for carbon particles in the nostrils, nasopharynx, or epiglottis is readily carried out. When clinical evidence of hoarseness or stridor is present, a trivial burn about the head and neck may imply involvement of the respiratory epithelium by smoke, resulting in laryngeal or pulmonary edema, with the possibility of death within 24 to 48 hours.[4, 19, 30, 39]

Baseline determinations of arterial blood gases and blood pH are an indirect measure of tissue hypoxia or initial acidosis. They provide the bases for the need for oxygen inhalation therapy, or the prompt administration of sodium bicarbonate.[15]

A tracheostomy is not usually performed unless the Po_2 falls below 80 mm. Hg and the Pco_2 rises above 45 mm. Hg.[26] Tracheostomy adds

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problems to the management of the patient, particularly when it is necessary to dissect in an area of devitalized, burned tissue. Tracheostomy is, however, the best way to facilitate gas exchange and to remove the viscous secretions (either by bronchoscopy or catheter suction) that may block the airway. Mucolytic agents added to the humidified oxygen system aid in liquefying secretions, facilitating their removal.[14, 29]

Baseline chest x-rays are also taken. Serial chest x-rays may disclose scattered areas of increased density, phlegm patching, and vascular crowding if chemical pneumonitis is present.[33, 37] Demonstration of bronchial casts on sputum smear, and sputum culture for pathogenic organisms are aids for the appropriate therapeutic approach and future management of the problem. The aim is the prevention of necrotizing tracheobronchitis which often requires mechanical ventilation and may result in a dreadful refractory hypoxemia.[6, 40]

ACUTE PHASE OF BURN SHOCK. To restore and maintain an adequate circulation, a large bore polyethylene catheter is threaded through a venous cut-down. A major vein in an upper extremity or the neck is preferable for cannulation. The catheter threaded into the superior vena cava can be used to administer fluids rapidly as well as to monitor central venous pressure. Blood samples for complete blood count, electrolytes and SMA_{12} are drawn, and infusion of lactated Ringer's solution is initiated.[16, 18]

The maintenance of normal cardiac output and blood flow from the onset of burn injury prevents hypoxia at the tissue level.[5] Therefore, aggressive fluid administration during the first 18 hours post burn, during which time 75 per cent of edema develops, is rewarding. Infusion of Ringer's lactate solution is begun in quantities which generally are in excess of the calculated recommendations of the Brooks or Evans formulas.[31, 34]

With a Foley catheter within the bladder for adequate measuring of the hourly urinary output, an initial urinary response is induced by infusing large volumes of Ringer's lactate solution particularly in the first 4 to 5 hours following injury. After the first 24 hours post burn, subsequent monitoring of the urinary output is extremely important as the danger of fluid overload increases.[41] The administration of fluid is adjusted to maintain an ideal urinary output of 1 ml. per kg. per hour.

Following burn trauma, tissue acidosis readily occurs even before it is detected by measurements of arterial pH. Shortly after the injury 98 mEq. of sodium bicarbonate is administered in order to effect an initial acid base balance.[32, 42]

PAIN. Soon after systemic fluid therapy is initiated, the relief of pain is considered. Pain is a subjective symptom which requires objective appraisal, to determine the extent and depth of the burn. In partial-thickness burns, pinprick sensation is usually retained, the burned surface is moisturized, white to pink in color, and blisters may be present. Pain relief is best provided by the application of cold soaks. Narcotics such as morphine, given intravenously in dosages of 2 to 6 mg. may also be administered if necessary, particularly in highly emotional individuals with a low pain threshold. Phenothiazine derivatives to promote restfulness are also of value in certain patients because, by their sedative actions, they allay anxiety.

Figure 1. Photograph of a patient shortly after being burned. Subclavian vein has been cannulated for administration of fluids.

Shortly after a major burn, confusion, disorientation, or somnolence is commonly observed. Their presence is related indirectly to the adequacy of circulation; therefore no narcotic or sedative is given to relieve anxiety or restlessness before the correction of hypoxia or dehydration has been accomplished.

EXTENT AND SEVERITY OF INJURY. When pain and anxiety have been relieved, a rapid assessment of the extent and severity of the injury is clinically established. The magnitude of the burn is calculated, using the "rule of nines." Gross clinical appraisal differentiates partial from full-thickness burn injury.[17]

ADJUNCTIVE MEASURES. Prior to the transfer of the patient from the accident ward to the intensive care unit, photographs are taken (Fig. 1) and chest x-rays are obtained. Radiologic baseline information about the state of the respiratory tract as well as knowledge of the exact position of the central venous pressure catheter is always helpful. Tetanus immunization is insured by the administration of fluid tetanus toxoid 0.5 ml. subcutaneously. If previous immunization cannot be documented, human hyperimmune globulin, 500 units, is administered intramuscularly.[38]

Since most severely burned patients may develop adynamic ileus, a nasogastric tube is inserted to facilitate gastrointestinal decompression, until peristalsis is re-established. Administration of Maalox, 30 cc. 3 times daily, via nasogastric tube and propantheline (Probanthine), 15 mg. three times daily, provides the best prophylaxis against stress ulcer.[13]

Intensive Care Unit

The intensive care unit of our institution provides the place where the period of burn shock is optimally managed until the period of total circulatory balance is reached, at which time the patient may be transferred to his own room.

EQUILIBRATION PERIOD. Adequacy of initial fluid replacement is reflected by the stabilization of vital signs. Stable blood pressure, slowing of an initially rapid pulse, progressive decrease in the hematocrit, and normal central venous pressure are clinical parameters useful in assessing the patient's course. However, hourly measurements of urinary output and urine specific gravity are, for all practical purposes, the most reliable parameters for assessing the adequacy of hydration.

In patients with cardiac, renal, or metabolic diseases, as well as in infants or the aged, careful monitoring of the central venous pressure provides one of the best indicators to control fluid administration. Clear-cut guidelines are programmed on a chart posted at the bedside, to preclude mistakes by any personnel involved in the management of fluid and electrolytic balance. Urinary output, urine specific gravity, gastrointestinal losses, and insensible losses are evaluated at 8 hour intervals with each nursing shift to maintain satisfactory control of the patient's intake. Body weight is noted daily.[2]

Following major burn trauma, there is alteration of cell membrane permeability, resulting in movement of sodium intracellularly as potassium in turn moves out of the cell into the extracellular fluid.[36] Serum electrolyte imbalances are therefore comon, and generally there is mild dilutional hypotremia during the early post burn period. In our practice, judicious administration of hypertonic lactated saline has effected the necessary correction of this hyponatremia during the second and third post burn days. Measurements of urinary electrolytes have been very helpful during this period to avoid complication of extracellular fluid hyperosmolality.

Potassium replacement, if required, is not initiated until 48 hours post burn.

During the first 24 hours following burn injury, there is usually a fall in serum bicarbonate as a result of tissue acidosis. Early administration of sodium bicarbonate, 88 mEq. intravenously, followed by hydration and restoration of electrolyte balance is usually instrumental in the maintenance of a satisfactory acid-base state.

It should be noted that, shortly after a patient is burned, there may be a moderately elevated hematocrit, which can rise as high as 55 per cent because of the loss of fluid through the burned area. Throughout the period of edema formation, capillary stagnation results in red blood cell aggregation or sludging of RBC with the production of capillary red cell "casts." This leads to a progressive fall in hematocrit which must be corrected frequently during the course of the patient's recovery.

PHASE OF DIURESIS. By the beginning of the fourth post burn day, there is a progressive rise in urinary output, heralding the period of reabsorption of edema fluid into the circulation. Curtailment of fluid administration becomes imperative. Blood urea, which is usually elevated during the early post burn period, begins to return to normal with the advent of

diuresis, and is a helpful parameter to measure at this time. Determinations of serum and urine osmolality are also helpful in verifying the maintenance of adequate electrolyte and fluid balance. It is extremely important to observe the pulmonary status carefully. Increased amounts of fluid in the intravascular compartment may lead to pulmonary edema.[7] Comparative chest x-rays from second, third, and fourth post burn days are also helpful in this regard.

Once peristalsis has returned, the nasogastric tube is removed, and diet progression is begun. A high caloric, high protein diet is initiated as soon as it is feasible, to cope with the tremendous demands that a healing burn will require.[21]

Because of the ever present danger of Curling's ulcer, it is our practice to maintain the patient on Maalox and anticholinergics as sound preventative measures.

Care of the Burn Wound

Preliminary Management. Burn wound care is initiated in the accident ward. Gentle scrubbing of the burned surface with Betadine scrub solution and rinsing with normal saline provides initial debridement of loose devitalized tissue. Often the patient is taken from the accident ward to the whirlpool, where initial thorough washing of the burn wound is done with Betadine solution. Immediate physical therapy to major and minor joints involved by the injury is initiated. Splinting the involved extremities in a functional position, especially the hands, is accomplished by the occupational therapist.[29]

Topical application of an antibacterial agent is not initiated until the status of the kidneys and lungs is assessed;[28] however, reverse isolation precautions are instituted immediately in a special burn cubicle, once the patient is transferred to the intensive care unit.

The decision to treat the burn wound by the open or closed method is based upon such factors as the anatomic location of the burn, age of the patient, state of health prior to injury, and history of pulmonary, kidney, or metabolic disease. In general, burns of the hands and feet are treated initially by the closed method, splinting the extremity in a position of function. Passive as well as active physical therapy is given twice a day.

When circumferential full-thickness injury to the extremities or thorax is present, anticipating the need for escharotomy is most important. If thoracic excursion is restricted, respiratory distress results. Also, severely ill patients often cannot report symptoms of arterial insufficiency of the extremities such as pain paresthesia, hypesthesia, and inability to move the fingers. Poor capillary return in an extremity is often the only objective sign influencing the decision to perform an escharotomy. Occasionally when initial examination of an area with a circumferential burn injury presents the possibility of either a restricted thoracic excursion or circulatory embarrassment, a conservative approach is inducted with frequent observation of the injury. A topical agent may be applied in order to keep the eschar moist and soft. In marginal cases, this measure may eliminate the need for escharotomy; however, circulatory embarrassment may not be evident until hours or days after the initial burn.

Figure 2. Patient prior to immersion in Hubbard tank. Sulfamylon cream is washed off in tank and burn wound is debrided of loose devitalized tissue daily.

Escharotomies, when needed in the extremities, are usually performed on the medial and lateral aspects of the affected limb. Because the incision is made through a contaminated wound into viable tissue, creation of a portal of entry for infection is unavoidable. Therefore, the gaping defect exposing viable muscle is immediately covered by a xenograft (porcine skin) to provide a barrier against bacterial proliferation. Chest incisions are usually placed along the anterior axillary lines and extended across the epigastrium.

CONTROL OF THE BURN SEPSIS.[35] Successful control of burn sepsis in our experience has been mainly the result of frequent burn debridement in the Hubbard tank (Fig. 2) to maintain cleanliness regardless of the method chosen to treat the burn wound or the topical antibacterial agent to be used. By the end of the first 24 hours post burn, when overall evaluation of the lung, kidney, and metabolic status of the patient has been done, topical application of any one of the effective antibacterial agents which are currently available is initiated. Ten per cent Sulfamylon cream or Betadine ointment is used when the decision to treat the burn wound by the open method is made. When the closed method is chosen, 0.5 per cent silver nitrate solution or Xeroform gauze with a bulky dressing is used.

It is important that one be aware of the disadvantages of the currently available topical antibacterial agents. Paracarboxybencene sul-

fonamide inhibits carbonic anhidrase in red cells, brain, chemoreceptor sites, and kidney tubules, leading to an intracellular acidosis. In patients with inhalation injury when pulmonary deficiency is the consequence, a rise in Pco_2 with a fall in arterial blood pH may be readily observed. Topical application of sulfamylon cream under these circumstances may further block the buffering mechanism of the lung. As metabolic derangement sets in as well, the buffering capacity of the blood is also reduced, resulting in an increased bicarbonate excretion by the kidney and bicarbonate conversion to carbon dioxide which must be excreted by the already damaged lung. An excess load of carbon dioxide in the blood stimulates the respiratory control mechanism and hyperventilation results. Furthermore, in the presence of hemoglobinuria or previous kidney derangement, retention of acid metabolites may compound the problem in acid base changes that are the result of blockage of the main buffering mechanisms of the body.

Other problems created by the use of sulfamylon cream are burning pain lasting for 10 to 15 minutes, particularly in partial-thickness burns; the occurrence of a maculopapular rash in the unburned areas of sensitive patients; and the interference of regeneration of viable epithelial islands.[27]

Dilutional hyponatremia and hypochloremia are the significant metabolic and biochemical changes attendant upon the use of hypotonic 0.5 per cent silver nitrate solution.[9] Staining of floors, walls, and clothes may very well be a vexing factor for hospital administration and laundry departments.

Burning pain upon application of Betadine ointment, intolerance by patients known to be hypersensitive to iodine, severe inhalation injury and the occasional rise in protein-bound iodine have constituted in our opinion the disadvantages of this topical antibacterial agent.[11] At times no topical antibacterial agents are used and instead bulky dressings with

Figure 3. Anesthetic segments of full-thickness injury are amenable to tangential excision with the Goulian dermatome.

Figure 4. Coverage of newly debrided areas with sheets of porcine skin as a biological dressing.

Xeroform gauze next to the burn wound are applied. Frequent dressing change and cleansing are necessary if bacterial growth is to be controlled.

Systemic antibacterial therapy using a broad spectrum antibiotic is usually initiated on the fourth or fifth post burn day when prophylactic penicillin or erythromycin is discontinued. Choice of antibiotic is based upon culture and sensitivity studies of the burn wound, urine, stool, sputum, and blood.[1]

AGGRESSIVE EARLY TANGENTIAL EXCISION OF BURN ESCHAR.[12, 23–25] The aggressive early tangential excision of the burn eschar is used in those patients first seen in our service shortly after the occurrence of burn injury in whom burn sepsis control has been inforced from the time of their arrival at the hospital. By the end of the fifth post burn day, when diuresis is basically returning to normal, careful clinical re-evaluation of the depth of burn injury is done. Anesthetic segments of full-thickness injury are amenable to gradual tangential excision with the Goulian dermatome (Fig. 3). After the patient comes out of the Hubbard tank, and under meperidine or morphine analgesia in conjunction with phenothiazine sedation, segmental tangential burn eschar removal is done until capillary bleeding is readily seen. Gauze pads impregnated with thrombine solution are applied for 10 to 15 minutes and are followed by compression to control capillary oozing. Immediate coverage of the newly debrided segments is then provided by commercial porcine skin grafts.[22] These Xenografts are maintained in place by circumferential compression dressings with Klinger rolls or by the application of elastic mesh gauze (Flexinet). These are subsequently soaked through with 0.5 per cent silver nitrate solution every 2 hours.

Full-thickness injuries encompassing also the subcutaneous or deeper tissues are tangentially excised in the operating room under neuroleptoanalgesia with intravenous ketamine. In selected patients recently recovered from burn shock, it has been possible to carry out aggressive tangential excision of large segments of deep full-thickness injury in the operating room as early as the ninth burn day. Coverage of the newly debrided areas is carried out with Xenografts (Fig. 4) and daily replacement of the biological dressing as well as cleansing, follows in the whirlpool. Silver nitrate soakings every 2 hours are, in addition, maintained around the clock.

Harvesting of autologous skin from limited donor site areas is procured during the same operating time for eschar removal. Autologous skin is storaged in petri dishes with penicillin solution at freezing temperatures. The donor sites are dressed with fine mesh gauze impregnated with thrombine solution and are left open to the air. It is possible, thus, to harvest autologous skin every ten days for storage purposes.

Objective nutritional balance, electrolyte balance, and the presumable decrease on excessive energy expenditure are among the definitive advantages provided by early burn eschar removal with prompt coverage with Xenografts.

Priority for autologous grafting is given to hands and joint regions in association with proper immobilization and splinting during the critical period of "graft take."[10] As early as possible thereafter, physical therapy is reinstituted or maintained in a progressive individualized program (Fig. 5).

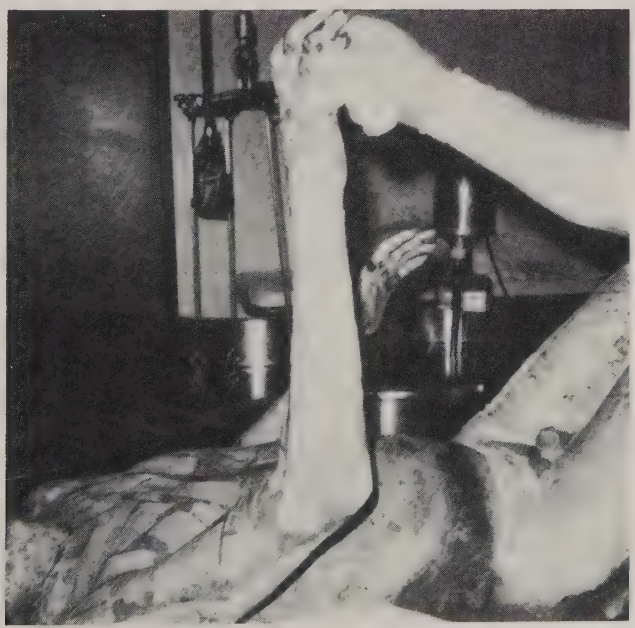

Figure 5. Successful autologous skin-grafting is followed by progressive physical therapy.

Figure 6. Mesh skin-grafting expedites coverage of granulating beds, especially when only a limited supply of autologous skin is available.

When the healthy granulations in the burn wound progress rapidly, and only a limited supply of the harvested autologous skin is available, mesh grafting facilitates final coverage (Fig. 6).[8]

AUTOCHTHONOUS ESCHARECTOMY GRAFTING

In selected clinical situations, such as burns on the dorsa of the hands, early aggressive tangential excision of full-thickness areas containing islands of partial-thickness injury has been carried out during the actual period of edema formation. Excision of these burned segments facilitates early wound closure with Xenografts. Appropriate compression-immobilization of the hands by splinting in a functional position is also done.

The excised full-thickness burn (eschar) is immediately placed in a petri dish with normal saline and penicillin solution. Under sterile conditions, "in vitro" debridement of the grossly devitalized areas of the eschar is performed. Following this, the eschar is subjected to enzymatic debridement by exposure to travase in normal saline for 48 hours. The resultant residual eschar has been found to harbor viable epithelial tissue and is subsequently maintained in a standard culture media solution until such time as the original donor site has smooth, healthy granulations and is free from edema. At this time the patient's own eschar has been successfully replaced to his original burn site. Optimal rehabilitation of the burned hand is therefore possible by using viable autochthonous escharectomy grafting.

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Choosing a Catheter for Central Venous Catheterization

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Central venous catheters (CVC) have become an integral part in the treatment of the critically ill patient. The percutaneous placement of those catheters directly into large central veins has made possible their long-term use. More peripherally placed catheters have such a high incidence of thrombophlebitis that their long-term use is impractical.[7, 19, 23] The standard sites for the placement of central venous catheters are into the subclavian vein, using both the supraclavicular[11, 24] and the infraclavicular[4, 10, 16, 19, 23] approach, and into the internal jugular vein.[8, 14, 20]

The placement and long-term use of these catheters are not without hazard. The incidence of complications, both immediate and long-term, has been shown to be inversely related to the training and experience of the person placing the catheter.[3, 4] Most reported complications of CVC's have occurred while using the "open technique" of catheter placement (see below) with the standard set-up of needle, syringe, and catheter.[5, 8, 16, 19, 20, 24] Certain types of complications can be eliminated or reduced with catheter design, even with less experienced operators. There are now several different catheter designs commercially available and suitable for central venous placement. This report examines several of these catheters and evaluates each as to how it affects the incidence of complications. The design and use of the catheter delivery unit are considered first, and then the catheter itself.

DELIVERY UNIT

There are three basic types of delivery units available: those which introduce the catheter through a needle, those which introduce the catheter over a needle, and those which are a combination of the two.

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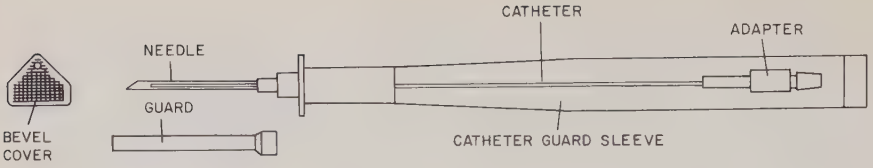

Figure 1. *Intracath* Deseret, Deseret Pharmaceutical Company, Inc., Sandy, Utah 84070.

Through-the-Needle Type

1. Intracath. This is the simplest design of the through-the-needle type of delivery unit. It consists of a needle, a catheter, and a catheter sleeve (Fig. 1). The unit can be supplied with either a "standard" or a Teflon catheter, and with or without a stylet. The cost of a needle with a standard 8 inch catheter without a stylet is $1.00 per unit (carton of 200).

The most commonly used procedure for introducing the Intracath catheter is an open technique. With the patient properly positioned, prepped, and draped, and using sterile gloves, the needle is removed from the catheter and protective sleeve, and connected to a syringe. The catheter is either left in the protective sleeve or removed and laid on the sterile drapes. The skin puncture is then made and the needle advanced while maintaining a mild negative pressure with the syringe. When the vein is punctured and a free flow of dark blood is obtained, the needle is advanced 1 to 2 mm. to insure that the entire bevel of the needle is in the vein. Again the free flow of blood is checked. The syringe is then removed and the gloved finger is placed over the needle hub. The catheter is then introduced through the needle the distance estimated necessary to place its tip near the right atrium. Again a free flow of blood is demonstrated and the IV attached.[5, 8, 16, 19, 20, 24]

The primary disadvantage of this open technique is the possibility of contaminating the catheter—even with the catheter in its protective sleeve and only its tip exposed.[10] Catheter contamination can come from anywhere, but it is mainly a function of a breakdown in sterile technique which in turn is a function of the experience of the operator.[4, 17] A second potential complication of the open technique is that of air embolism, either from not properly positioning the patient or forgetting to place the finger over the needle hub.[3, 15, 16, 20, 24]

A closed technique for inserting an infraclavicular subclavian Intracath has been described.[10] The needle of a completely assembled Intracath is inserted into the skin and advanced to the hub in a routine direction for this approach. The catheter is advanced fully and the needle withdrawn. The intravenous fluid is then attached and the bottle is lowered to check for flashback of blood to insure the catheter is in the vein. If the catheter does not advance after the needle is inserted fully, the needle is withdrawn and a new direction is tried. Frequently there is no flashback of blood when the needle enters the vein and the only indication that the needle is in the vein is that the catheter "threads."

This closed technique for inserting a subclavian Intracath has been used in over 600 venipunctures with no serious complications of catheter insertion, and with a much lower rate of infection than with the open

technique. The low rate of complication with catheter insertion was attributed to an accepted 10 per cent failure rate for venipuncture rather than persisting with multiple blind punctures. The low rate of infection was attributed to not directly handling the catheter. In addition, this reported low morbidity was unrelated to the experience of the person placing the catheter.[10] The main disadvantage of the technique is the 10 per cent failure rate for cannulating the vein.

The main advantages of the Intracath are that it is simple, easy to understand and use, and versatile. The 14-gauge needle can be used not only to insert its own catheter, but also to insert pacemakers. A significant complication of the Intracath is the danger of shearing and embolizing the catheter if it is withdrawn with the needle in place.[5] This complication is rare and the warnings are well stated by the manufacturer. However, because of the serious medical and medicolegal implications of removing an embolized catheter, the shearing hazard should be a significant factor in choosing the catheter. One last disadvantage of the Intracath and of all through-the-needle delivery units is that the hole made in the vein is larger than the catheter, but this may only become a problem in a patient with a bleeding diathesis.

2. Subclavian Intrafusor. This unit is more complicated than the Intracath, and is designed to be used completely assembled. Unlike the Intracath, it cannot be used disassembled. The basic components of the unit are the needle, catheter, protective conduit, actuator with "Retracta-

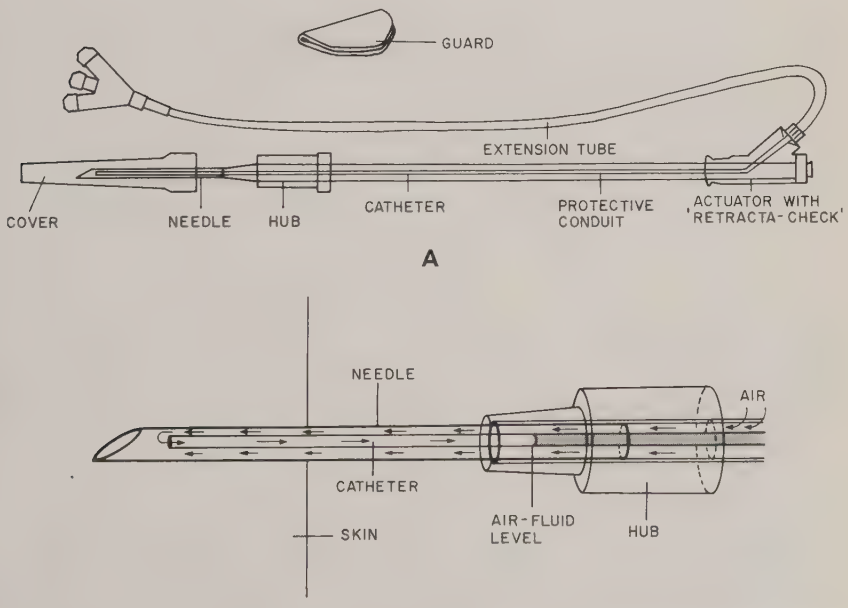

Figure 2. *A, Subclavian Intrafusor*, Sorenson Research Company, Salt Lake City, Utah 84115. *B*, Detail of *Subclavian Intrafusor*, showing needle, hub, and distal catheter. When a negative pressure is applied to the column of fluid in the catheter after the needle has punctured the skin, but prior to venipuncture, that pressure is equalized by air leaking in through the hub around the catheter. An air-fluid level is then seen advancing in the catheter.

Check," and extension tube (Fig. 2). The unit is supplied in several sizes, but has only one standard catheter and no stylet. The cost of a unit is $2.25 (over 2 cases at 100 per case).

Because the delivery unit cannot be disassembled, the catheter can be inserted only by a closed technique; thus, catheter contamination is minimized. The manufacturer's suggested technique for using this unit is to fill the catheter with the intravenous fluid, make the needle puncture, and then drop the IV fluid bottle below the level of the patient. The needle is then advanced through a longitudinal slit in the conduit by moving the actuator forward. When the catheter is advanced fully, the conduit is removed. Withdrawing the catheter once it has been advanced is hindered by a device called the "Retracta-Check," although with enough force the device can be overpowered and the catheter sheared.

It has been the experience of this author that in making deep venipuncture, the method of lowering the IV bottle is not completely reliable. If one does not drop the bottle low enough, there is not always a flashback of blood, and if the bottle is dropped too low, air will flow into the proximal end of the needle and into the catheter (Fig. 2*B*), filling the catheter and IV tubing with air.

A second more reliable technique for using this unit is the following. The catheter is first filled with normal saline and an empty 5 cc. syringe is attached. The needle is manipulated with the right hand (if the operator is right handed) and the syringe with the left. The skin is punctured with the needle and the needle is advanced 2 to 3 mm. in the appropriate direction. Entry into the vein is then tested by gently aspirating 0.5 to 1.0 cc. of saline from the catheter, creating a negative pressure within the needle lumen. If the vein has not been entered, the negative pressure is equalized by air flowing from the needle hub around the catheter (Fig. 2*B*), and an air fluid level is seen advancing in the catheter. The syringe is then gently emptied, returning the exact amount of saline to once again fill the catheter. The air in the catheter flows out the needle hub. The needle is again advanced 2 to 3 mm. and entry into the vein tested.

When the vein is entered, the negative pressure created in the needle is equalized by blood flowing from the vein, and a blood level is seen advancing in the catheter. The needle is then advanced 1 to 2 mm. more to insure that the needle bevel is inside the vein, then the catheter is advanced. When the catheter has been advanced the needle is withdrawn. This author has used this technique in over 50 subclavian venipunctures and found it to be as reliable in determining entry into the vein as is the open technique with the Intracath.

The obvious advantages of the Intrafusor unit is that it is a completely closed system with no chance of iatrogenic catheter contamination or air embolism. Catheter shearing is theoretically possible, but the chance of doing so is markedly reduced. A possible weakness of the unit is that there is no "feel" to the catheter advancement mechanism. The only indication that the catheter has met an obstruction and is not advancing is that it buckles inside the conduit. This inability to "feel" when the catheter meets obstruction may increase the chance of intimal trauma and vein perforation.

3. Medi-Cath. This is a self-contained closed system designed to in-

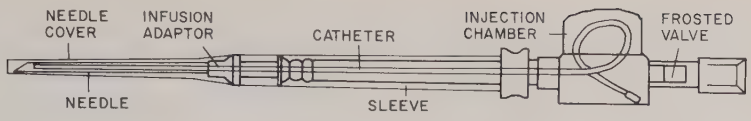

Figure 3. *Medi-Cath* Intravenous Delivery Unit with Silastic Silicone Catheter, Chesebrough-Pond's Inc. Hospital Products Division, 485 Lexington Ave., New York, New York 10017. Silastic is a registered trademark of the Dow Corning Corporation.

ject its pliable Silastic catheter into the vein. The unit consists basically of a needle, sleeve injection chamber, and silicon catheter (Fig. 3). The unit is supplied in only 2 sizes – 14 or 16 gauge by 2 inch needle and 9 inch radiopaque catheter. The cost of a unit is $3.24 (case of 60).

There is only one technique for introducing this catheter. The unit is first completely filled with intravenous fluid and the skin punctured. The manufacturer suggests that about 0.5 cc. of fluid then be expressed from the unit by *gently* squeezing the injection chamber. The needle is then advanced in the appropriate direction. Expressing the fluid prior to advancing the catheter decreases the pressure in this closed system. When the vein is entered, the pressure is equalized by blood flowing into the injection chamber. The needle is then advanced 2 mm. and the injection chamber is depressed sharply, injecting the catheter into the vein. The needle and entire delivery unit are then separated from the catheter, leaving only the catheter with the IV connector on its end.[22]

The advantages of this unit are as follows. It is impossible to shear the catheter and practically impossible to get an air embolism. The pliable catheter will not perforate anything and can float in the stream of blood, moving past valves, bifurcations, and kinks in the veins.[12] Only the catheter and IV connector are left on the patient and iatrogenic catheter contamination is virtually eliminated. There are three disadvantages of the unit. (1) If the catheter becomes occluded it is almost impossible to flush and open it because the catheter will leak at the catheter-IV connector junction. (2) The unit is expensive. (3) The unit is complicated and requires some training and practice before it can be successfully used.

Over-the-Needle Delivery Unit

E-Z Cath with Y tube. Basically, this catheter system consists of a needle stylet, inserter, catheter Y adapter, stylet plug, and sleeve (Fig. 4). The catheter is made of Teflon and is supplied in several sizes. The cost per unit is $1.10 (carton of 200).

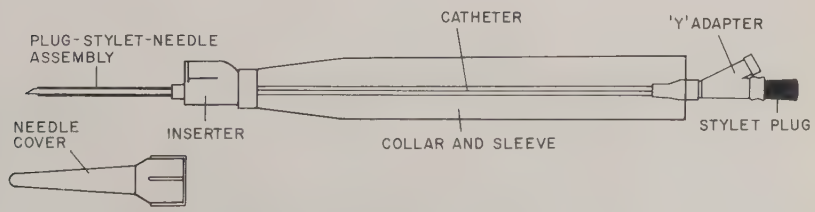

Figure 4. *E-Z Cath* Intravenous placement unit with "Y" Adapter *Deseret*, Deseret Pharmaceutical Company, Inc., Sandy, Utah 84070.

The unit is used by first attaching a syringe to the Y connector. The needle inserter is grasped in the right hand (if the operator is right handed) and the syringe manipulated with the left. The skin is punctured with the needle/catheter and advanced in the appropriate direction, maintaining negative pressure with the syringe. (This system is airtight.) When the vein is entered blood will return through the catheter into the syringe. The unit is advanced 2 mm., and the catheter is advanced, holding the stylet plug fixed. This maneuver hopefully advances the catheter into the vein over the needle. The needle can then be completely removed from the catheter.

The advantages of this catheter are: it is impossible to shear; air embolus is almost impossible; and the hole made in the vein is the same size as the catheter, possibly an important factor in a patient with bleeding diathesis. There are significant disadvantages to this catheter for its long term use as a CVC. First, unless the vein is very close to the skin, it is very difficult to thread the catheter over the needle and into the vein because of tissue resistance and relative catheter flexibility. The critical move is trying to hold the needle steady in the vein, with the inserter, while advancing the catheter and holding the stylet plug steady. In this author's experience, the failure rate in catheterizing deep veins has been unacceptably high. Second, because the catheter is threaded over the needle it is contaminated its entire length by the skin, possibly making long-term use hazardous.

Combination Delivery Units

Argyle Intramedicut Catheter. This unit consists basically of a syringe attached to a needle over which is a Medicut cannula; an Intramedicut catheter; and a protective sleeve (Fig. 5). The catheters are made of vinyl with a radiopaque line down their length and they come in several lengths and gauges. The comparative price for an 8 inch catheter is $2.50 per unit (lots of 20).

The venipuncture is made using an open technique slowly advancing the needle with gentle aspiration of the syringe. When blood returns, the needle is advanced 2 mm. to insure the medicut catheter is in the vein. The needle is then removed and the catheter opening occluded with a sterile-gloved finger. The Intramedicut catheter is then advanced

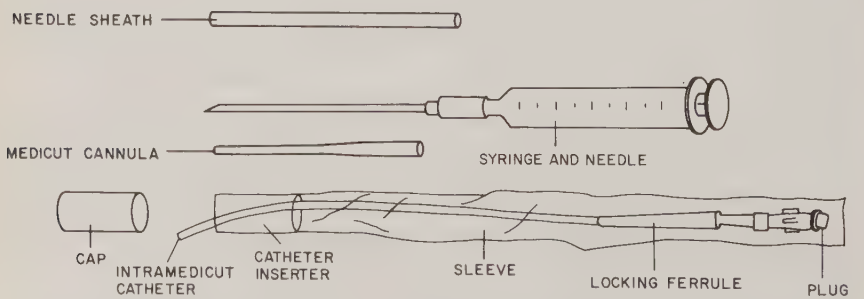

Figure 5. *Argyle* Sterile Intramedicut Catheter Kit. Aloe Medical, 1831 Olive Street, St. Louis, Missouri 63103. Figure does not show sterile drape and rigid molded tray, which are also included in the kit.

through the Medicut catheter. Once the second catheter is in the proper position the Medicut catheter is withdrawn and locked into place at the IV connection end of the Intramedicut catheter.

The obvious advantages of this system are: it is impossible to shear either catheter; the Medicut catheter is tapered at the end to minimize the hole made in the vein; and the unit is simple and easy to learn to use. The primary disadvantage of the unit is that an open technique, with all its potential for catheter contamination, must be used to insert the catheter.

CATHETERS

When considering catheters, two properties are important: stiffness and thrombogenicity.

Stiffness

In general, the stiffer the catheter, the higher the likelihood of intimal trauma and resulting phlebitis.[13, 18] Erosion and perforation of the vein is another potential hazard of a stiff catheter.[1, 2, 6] Perforation of the vein can occur as the catheter is being placed, or at variable times after the catheter has been placed. Perforation of a vein by a central venous catheter has been reported with resulting hydrothorax,[2] hydromediastinum,[1] and extravasation of fluid into the neck, causing carotid sinus pressure and bradycardia.[6] Even perforation of the right ventricle causing cardiac tamponade has been reported.[5]

Of those catheters listed in this paper, it would seem that only the Medi-Cath Silastic catheter is so flexible as to eliminate the risk of vessel perforation and decrease the risk of intimal damage.

Thrombogenicity

The ability of plastic to initiate thrombus formation and form a fibrin layer is seen in both vascular catheters and grafts. Because the fibrin layer that forms over the plastic is, in general, nonthrombogenic, the clot does not usually propagate. In vascular catheters, the fibrin deposit begins at the areas of intimal contact and injury and propagates circumferentially along the catheter.[13] Formanek et al.[9] found that Teflon catheters were approximately twice as thrombogenic as polyethylene or siliconized polyethylene arterial catheters. However, Hoshal et al.[13] showed fibrin sleeves to be present around all subclavian catheters studied (polyethylene and Teflon).

The exact fate of the fibrin sleeve is not known. It is possible that they are slowly absorbed after the catheter is removed, although they have been demonstrated many days after the subclavian catheter has been removed.[13] The sleeve may also embolize at the time the catheter is withdrawn.[9] This embolization is obviously more important in arterial than in venous catheters. Thrombectomy is required in approximately 2.3 per cent of patients following arterial catheter withdrawal in arteriography.[21] It is possible that, given the conditions of hypotension, hypercoagulation, and intimal damage, venous coagulation and emboli-

zation can become a significant problem in catheterization of major veins.[18]

Embolization of a large clot associated with a subclavian catheter was speculated as the cause of death in 4 reported cases.[13, 18] A double-up catheter in the superior vena cava with thrombus formation was implicated as the cause of superior vena cava obstruction in another reported case.[15]

CONCLUSION

Careful consideration of central venous catheter design is essential to minimize complications associated with the placement of those catheters, especially if they are placed by inexperienced operators. The incidence of the following complications can be altered by catheter design alone.

Catheter shearing has been eliminated by either inserting the catheter over the needle (Deseret EZ Cath with Y connector, and Argyle Medicut Cannula), or by manipulating the catheter with only a fluid stream (Medi-Cath). Shearing has been reduced by adding a device which retards catheter withdrawal in a through-the-needle delivery unit (Intrafusor).

Air embolism can be reduced by using a closed system (Medi-Cath, Intrafusor, Intracath using a closed technique). Obviously, if a catheter is in place in a central vein, and if the other end of that catheter is left open to the air, air embolism is possible with any catheter design.

Catheter contamination can be greatly reduced, first, by preventing catheter contact with the skin as the catheter is threaded into the vein (all through-the-needle catheters), and second by preventing any catheter exposure as in closed systems (Intrafusor, Medi-Cath, Intracath with closed technique).

Venous perforation may be prevented by using soft, pliable catheters (Medi-Cath).

Intimal trauma is a source of phlebitis and may be prevented by using a soft, pliable catheter.

Thromboembolism. A truly nonthrombogenic material is not as yet available.[13] Probably, by preventing phlebitis, through the use of soft, pliable catheters, significant thrombosis and embolization can be greatly minimized.

Obviously, not all complications of central venous catheter placement can be prevented by catheter design alone. For example, trauma caused by improper manipulation of the needle, or contamination of the catheter by improperly preparing the skin have no relationship to catheter design. There is no replacement for experience or experienced supervision in carrying out proper technique.

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Interpretation of Central Venous Pressure

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In the management of patients with major trauma, we find a progressive fluid deficit that matures to its maximum degree within hours. From a circulatory standpoint, the patient with a crushed pelvis or a 40 per cent body burn is similar to others with generalized peritonitis or intestinal obstruction. As the plasma volume is lost into the site of injury, the so-called third space, the interstitial fluid shifts into the plasma compartment to restore the lost volume and thereby buffer the losses until both compartments are depleted. Unless the losses can be replaced promptly and in adequate volumes, the patients will go into shock, i.e., a state of inadequate perfusion. Add to this simple state of hypovolemia an impaired myocardium or severe sepsis and the patients become threatened with the loss of all three components of effective circulation, i.e., the pump, the volume, and the vascular tone.[9]

In the evaluation of an injured patient, it is frequently difficult to assess the state of the circulation. Toward this end, the use of central venous pressure has greatly improved our ability to identify how much fluid can be given, and at what rate it can be accepted by the patient. We have chosen patients with major infection, intestinal necrosis, massive body surface burns, and a myocardial contusion to demonstrate the many variables that are at play in various states of shock and how the central venous pressure can be an important guide in restoring the circulation to normal.[3]

From cardiac catheterizations studies,[1, 2] there is evidence that the normal range of central venous pressure extends from −2 to +7 cm. H_2O. Prior to 1950, many authors accepted values up to 15 cm. H_2O, but this referred to the peripheral, not the central, venous pressure. One can infer that if 7 cm. H_2O is the upper limit of normal, then 8, 9, and 10 cm. are borderline and 13, 14, and 15 cm. are consistent with impending heart failure.

Considering the fact that this is a bedside measurement, it is not the exact reading that is so important as the response of the CVP to an in-

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fusion of intravenous fluids. If the pressure is 2 cm. and rises promptly to 7 cm. following the rapid infusion of 250 ml. of fluid, there is marginal cardiac compensation and caution must be exercised in further fluid therapy. On the other hand, if the pressure is 7 cm. and remains there after 2000 ml. of fluid, then there is reason to infuse more if the clinical findings warrant it. Unfortunately, the estimate of the level of the right atrium, the zero baseline, is rather gross. Some authors feel that it is at the mid-lateral position of the chest,[8] others say that it is 10 cm. from the dorsal spine,[4] and still others that it is in line with the anterior third of the chest. We favor the anterior third of the chest as the baseline in a patient with a normal chest configuration lying on a firm surface.

In reference to the term "low venous pressure," it is well known that a normal patient may have a zero or even −2 cm. of water pressure when the tip of the catheter is known to be in the right atrium during cardiac catheterization studies. Furthermore, in our experiences with hypovolemic patients, the venous pressure never falls below −2 cm. of water, regardless of the severity of the fluid deficit. It is important to realize that there is an overlap of normal and low venous pressures. In a patient with a normally compensated heart we usually find that the venous pressure is around zero to 7 cm., but the trained athlete may well have a zero CVP at rest and −2 cm. in exercise.

According to Weil,[8] "central venous pressure measures the competence of the heart to expel the volume of blood presented to it." It expresses a relationship between the caval blood volume and the right heart function. For example, if a normovolemic patient has a severe myocardial infarct, the venous pressure will rise immediately toward or beyond 15 cm. of water, and as cardiac compensation returns, the venous pressure will fall below 15 cm. toward zero. If a patient with a normal heart is over-hydrated or over-transfused, the venous pressure usually will rise and fall in the same fashion. On the other hand, if the vasomotor tone is decreased, as in sepsis or because of a bee sting or any other form of sympathetic interruption, the arteries and veins will dilate and large volumes of blood may be given without a rise in the venous pressure. Wilson[9] has compared the circulation to a three legged stool which is supported by three forces – the heart, the blood volume, and the vascular tone. It is not unusual to find patients with poor heart function who develop infections, hemorrhage, or dehydration, and thus two legs or possibly all three legs of the stool are impaired to varying degrees. A few examples will demonstrate these points.

Mr. E was admitted in coma with no history. Blood pressure 90/50, skin mottled and cool, pulse 140, respirations 32. There were crackling rales over both lower lung fields, there were no murmurs and there was no sign of cardiac enlargement. The abdomen was distended and silent. There were 50 ml. of urine in his bladder. The specific gravity was 1.026. The CVP was −2 cm. and after 4 liters of fluid and blood, the vital signs had stabilized, urine output rose to 30 ml. per hour and the venous pressure rose to +2 cm. of water. At this point, the patient became arousable but died shortly thereafter. At post mortem, he was found to have bilateral confluent pneumonia with an empyema on the right side and massive intestinal necrosis. Although nothing could have been done to save

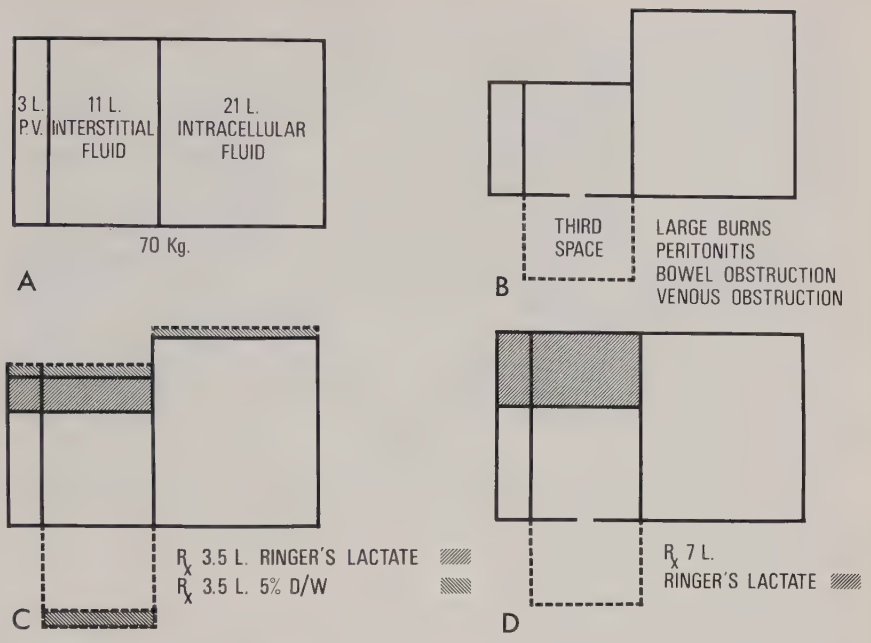

Figure 1. *A*, Normal distribution of body fluids: plasma, 3 liters; interstitial fluid, 11 liters; intracellular fluid, 21 liters. *B*, The extracellular fluid deficit due to sequestration at the site of injury. Note that the intracellular compartment does not contribute to the repair of the extracellular deficit in the early state of the disease. *C*, The poor effect of replacement with half Ringer's and half dextrose in water shows that water permeates all compartments. Note that the intracellular space is overexpanded, the third space is aggravated, and the extracellular space is inadequately restored. *D*, The response to replacement with balanced salt solution (Ringer's solution).

this patient, the value of CVP determination was clearly demonstrated. The tachycardia, hypotension, and crackling rales would have been consistent with heart failure, but the venous pressure of -2 ruled out this possibility and indicated that the patient could be hypovolemic, which he was shown to be. This patient had two defects, both of which tended to lower the CVP, i.e., hypovolemia and sepsis, which is associated with peripheral vasodilatation.

O.C. is a 44 year old man who had a perianal abscess that had progressed to a large scrotal abscess with surrounding cellulitis and mottling of the skin of both thighs. In addition, he had subcutaneous emphysema which extended up to his clavicles. He had a rapid pulse, a low blood pressure and a CVP of −1 cm. of water. This patient had the type of massive infection in which a major portion of his extracellular fluid would be sequestered at the site of injury, as opposed to a patient with cholangitis or pyelonephritis where relatively small amounts of fluid are trapped at the site of infection. Here the venous pressure was relatively low and indicated that fluid replacement could be undertaken safely.

E.G. was a 50 year old woman with generalized peritonitis of 4 days duration who was dehydrated, had a rapid tachycardia, hypotension,

oliguria and a CVP of –2. She was given 12 liters of intravenous fluids in 6 hours, at the end of which time the venous pressure had risen to 5 cm. of water. At this point, her vital signs had stabilized, her hourly urine volume was over 50 ml. and she tolerated an appendectomy for a perforated appendix. The important thing to note here is that 12 liters of fluid were given in a rapid but controlled manner into the 3 liter plasma space from which it diffused rapidly throughout the extracellular space including the third space (Fig. 1). Her tissue perfusion had been markedly compromised by the loss of a large amount of fluid into the peritoneal tissues where it was unavailable as blood volume. Although the degree of fluid deficit was thought to be large, the venous pressure measurement served as a guide to a safe endpoint of fluid therapy.

In reference to large body surface burns, Moyer[6] found that the CVP was a more reliable guide to fluid replacement than the Evans formula and, in general, patients use much more fluid than the formula would have indicated.

G.J. is a 42 year old man who survived a 95 per cent second and third degree burn (Fig. 2); the rate of fluid therapy was monitored by the CVP and the urinary output. He received 10 liters of fluid daily for 4 days, i.e., 40 liters intravenously, and excreted 5 liters of urine during this time. The fluid lost into the site of injury constituted an obligatory loss of plasma volume and interstitial fluid. The sudden development of a "third space" produced shock from hypovolemia. It is here that the CVP monitor is indispensable since it permits the rapid intravenous infusion of fluids in volumes that would overload the normal patient but without which the hypovolemic patient will not survive.

In some respects the CVP is like a speedometer, in that it tells us how fast we can infuse the fluid; if there is a rapid rise in the pressure, it tells us when to stop. On the other hand, it is possible that an excess of fluid may be infused without a rise in CVP since the venous bed can vasodilate to accommodate the increased volume. However, when the vital signs have stabilized, the urine volume is 30 to 50 ml. per hour, the patient is alert, the skin is warm and dry, we then have a normal state of perfusion and fluids would not be pushed beyond daily requirements.

J.R. is a 27 year old man who was seen 10 days following an automobile accident in which his only known injury was an undisplaced rib fracture on the right. He was pale, cool, and confused, had a blood pressure of 110/80, a pulse of 120, and became dizzy when sitting erect. He did not have a pneumothorax, hemothorax, or hydrothorax by x-ray examination, and both lung fields were clear. His urine specific gravity was 1.028 on a random specimen and his venous pressure was over 15 cm. of water; an EKG was consistent with myocardial damage. Following rapid digitalization, the venous pressure fell promptly to 7 cm. of water, and fluids were given intravenously to restore a normal fluid volume. This patient had both myocardial insufficiency owing to the steering wheel injury and hypovolemia because of poor oral intake for 10 days. If the hypovolemia had been treated without the knowledge that there was a high venous pressure from the contused heart, the patient would have been pushed into frank congestive heart failure. A high CVP is usually due to pump failure and is always an indication of serious functional im-

Figure 2. *A*, A patient with second and third degree burns of 85 per cent of body surface who required 40 liters of fluid in 4 days to maintain stable vital signs and normal urine volume. He also required 4 skin grafting operations during his 6 months in the hospital. *B*, One year later he returned to full employment.

Table 1. *Central Venous Pressure*

NORMAL OR "LOW" CENTRAL VENOUS PRESSURE
Hypovolemia
dehydration, burns, hemorrhage, peritonitis, intestinal obstruction, fistulas, diarrhea
Hypervolemia
with marked vasodilation, with hyperkinetic state
Hyperkinetic state
hyperthyroidism, arteriovenous fistulas, fever
Vasodilatation
sepsis, sympathetic interruption, vasodilating drugs
HIGH CENTRAL VENOUS PRESSURE
Normovolemia
with cardiac decompensation, inflow obstruction
Hypovolemia
with *severe* cardiac decompensation
Hypervolemia
polycythemia, overhydration
Inflow obstruction
superior vena cava compression, pericardial disease, pulmonary stenosis, pulmonary embolus

pairment. Fortunately this patient's heart responded promptly to digitalis and once the CVP had fallen to 7 cm. it was safe to proceed with vigorous fluid replacement.

Large fluid deficits are likely to occur in two main forms: (1) losses from the body, e.g., vomiting, diarrhea, small bowel, biliary or pancreatic fistulas; and (2) losses into tissues or cavities from which the fluid will later be reabsorbed, e.g., burns, effusions, operative site, trauma, and inflammation. Whereas patients in the first group will have a wide variation of electrolyte losses, those in the latter group uniformly lose extracellular fluid into the areas of fluid sequestration. In the management of massive burns, Moyer[6] has shown how effectively fluid deficits can be met with balanced salt solution. In the treatment of massive hemorrhage, Moore[5] has shown that the interstitial fluid will equilibrate with the plasma volume, but that the intracellular, or potassium compartment will not yield its fluid for the repair of a deficit in the extracellular or sodium compartment. On the other hand, the loss of circulating blood volume stimulates baroreceptors in the right atrium as well as the secretion of antidiuretic hormone, aldosterone, and catecholamines. These homeostatic responses will be reflected in rapid shifts in both the central and the peripheral circulation and under these circumstances the CVP can be an extremely useful guide. As can be noted in Table 1, it is possible to have a normal or a high CVP in the presence of normovolemia, hypovolemia, and hypervolemia. Thus, changes in the three variables, i.e., blood volume, vessel tone, and cardiac function, may occur alone or in several combinations. These changes may represent increases or decreases in

function, and it is the degree of change that will ultimately determine the state of the circulation and the CVP.

An interesting variation has been identified in several patients in which the CVP was 0 to –2 cm., i.e., within normal range, in the early phase of hypovolemia. As the situation became progressively worse the cardiac output fell and consequently the coronary perfusion was reduced, resulting in a failing myocardium. In this circumstance the CVP is likely to rise to 20 to 25 cm. Whereas a very high CVP usually is an indication to restrict fluids, in this situation fluids should be given so that the cardiac output can improve, thus allowing for better coronary perfusion. Recently in such a patient the CVP rose from 25 to 33 cm. during the period of vigorous fluid replacement and then it rapidly fell to 5 cm. as myocardial function returned to normal.

In our experience with CVP determinations in more than 1500 patients, we have found that it provides several advantages: (1) it is a constant monitor of the heart function in relation to blood volume; (2) it allows direct readings, using inexpensive disposable equipment; (3) it can be rapidly inserted at the bedside through the subclavian vein or internal jugular vein with a low complication rate in experienced hands; (4) it provides an excellent route for infusions of blood, fluids, drugs, and parenteral hyperalimentation.

SUMMARY

CVP is a product of heart function, blood volume, and vascular tone. The normal range is from –2 to +7 cm. of water. Since the zero point is only an estimate of the level of the right atrium, the response of the CVP to an infusion is more important than the initial reading. A rising venous pressure is an indication of relative hypervolemia, cardiac decompensation, or both, but in any case fluids must be restricted. A high venous pressure in a hypovolemic patient indicates severe cardiac decompensation and efforts to improve the cardiac output must precede volume replacement. When patients with known heart disease become ill or require an operation, the CVP becomes an important guide to fluid management. It is also indicated in patients requiring massive fluid replacement, e.g., major injuries, burns, peritonitis, sepsis, and intestinal obstruction, since they may require infusions of two or three times their plasma volume within a few hours.

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Ankle Pressures in Arterial Occlusive Disease Involving the Legs

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Martha A. Mackereth, R.N.

Ankle blood pressure, as determined with the Doppler ultrasound flow detector, is a simple, safe, and reproducible technique that offers objective information not otherwise available to the clinician. The information correlates nicely with insight gained from history and physical examination. Ankle blood pressures can be obtained as part of basic medical management or through the preoperative, operative, and postoperative phases of surgical treatment. Accordingly, we now employ ankle blood pressures routinely as a source of objective information that aids in the evaluation and management of peripheral vascular insufficiency. This report serves to focus attention on the application and usefulness of the ankle blood pressure determination based on our experience over the past 5 years.

THE CONCEPT OF ANKLE PRESSURES

Despite the increasing complexity of current medicine, clinicians rely upon information provided by the history, physical examination, stethoscope, and blood pressure cuff. Simple arm blood pressure determination provides the most elegant set of numbers in all of medicine. But the concept of blood pressure determination has not been applied to peripheral vascular problems, since a stethoscope is virtually insensitive to the distal arteries. Now with the ultrasound flow detector, we possess the ability to monitor peripheral vessels and with a traditional blood pressure cuff one can obtain "ankle blood pressures."[1, 6, 7, 8, 16, 20, 22, 23]

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We have employed a light, portable ultrasound flow detector which appears to be indestructible.* The dorsalis or posterior tibial artery is monitored while the cuff is inflated above systolic pressure. As the cuff is deflated, arterial flow resumes and is immediately heard on the Doppler. This point represents systolic pressure as recorded on the sphygmomanometer. It is a true "opening pressure," not the flow-turbulence pressure that produces the usual systolic reading with a stethoscope. The difference seems insignificant.

Ankle pressure should approximate arm pressure. The propagation of flow waves outward from the heart and the elasticity of the arterial walls may augment the pressure at certain points. Thus pressure higher or lower than that obtained at arm level may be recorded. The individual with an arm pressure of 150/78 mm. Hg may have an ankle pressure of 140 to 160. This same cuff can be moved to the calf or thigh to obtain blood pressure readings in the same manner. The physician may then employ gradient pressure data from the entire leg in his approach to peripheral vascular problems.

Upon reviewing our data we realize that resting ankle pressures offer information that aids clinical thinking in several ways. The actual pressure is important since the patient who describes nocturnal rest pain with a slightly discolored toe can have a femoral artery occlusion with an ankle pressure of 30. This number then represents the perfusion pressure offered to the distal tissues. With a simultaneous arm blood pressure of 150/78, the aorta-to-ankle gradient measures an impressive 120 (150–30), while actually the ankle pressure is only 20 per cent of arm pressure (30/150 = 20 per cent). We find the "actual" pressure readings and the ankle-to-arm "per cent" most helpful; therefore, our observations will include both determinations.

ANKLE PRESSURES AT REST

We have grouped our data into three categories to present the information obtained from over 3000 ankle pressure determinations performed through June 1972. These include "asymptomatic normals," "intermittent claudication," and "tissue threatening ischemia." The categories are useful to the clinician dealing with peripheral vascular disorders.[1, 19, 20, 22, 23]

Figures 1, 2, and 3 detail the observations in simplest form. Each dot represents one patient. If a patient was checked at regular intervals over 3 to 4 years for intermittent claudication and remained stable, his data would be entered only once. However, if the vascular insufficiency worsened and the patient developed a non-healing, ischemic ulcer as a new entity, he would appear in both groups, i.e., "claudication" and "tissue threatening ischemia."

The "asymptomatic normal" (Fig. 1) is defined here as the individual free of symptoms who possesses distal pulses at the dorsalis and/or posterior tibial level and shows no physical signs of arterial insufficiency.

*Parks Electronics, Beaverton, Oregon

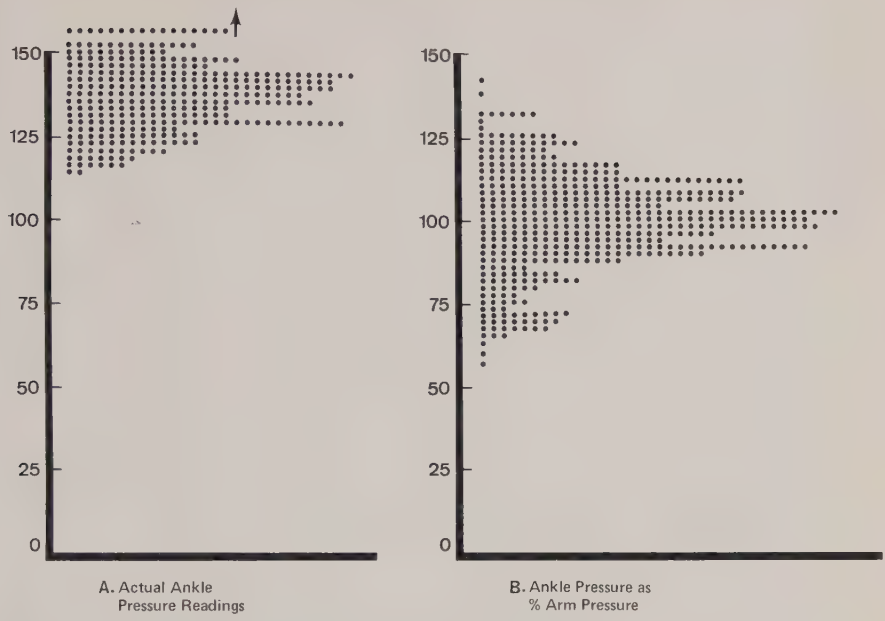

Figure 1. Asymptomatic "normals."

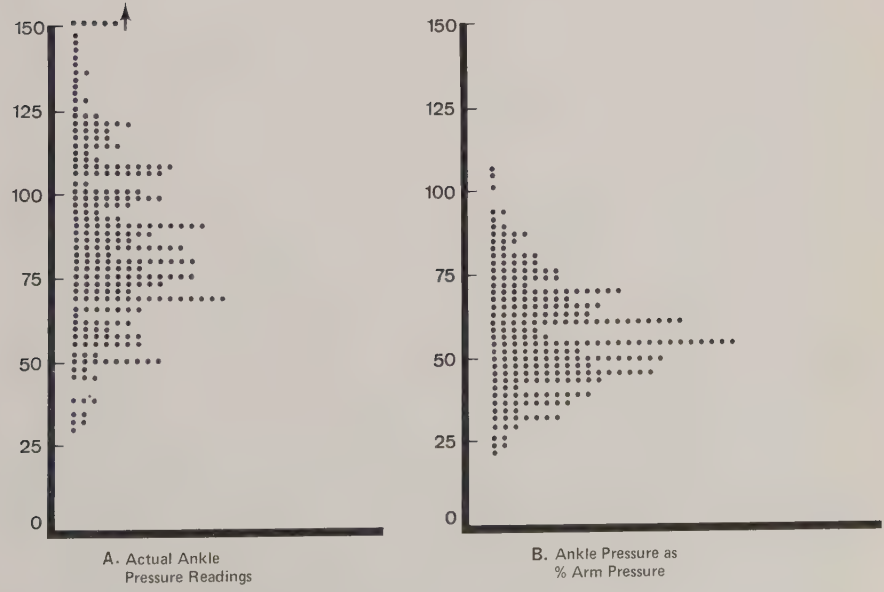

Figure 2. Intermittent claudication.

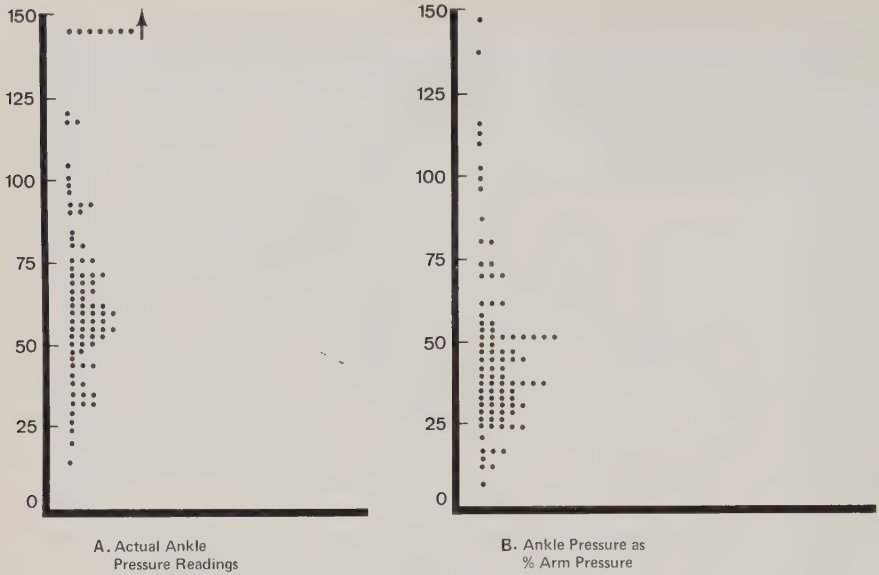

Figure 3. Rest pain and non-healing ulcers.

Many of the individuals tested were aging and undoubtedly had silent atherosclerotic changes in their vessels. Nonetheless, they are considered asymptomatic normals. The actual ankle blood pressures varied markedly (Fig. 1*A*) as would be the case in arm blood pressures taken from any randomized population. If these values are presented as per cent of arm pressure, they produce a bell-shaped curve with most of the points ranging from 85 to 115 per cent of arm pressure (Fig. 1*B*). This spread of 30 points (85 to 115 per cent) is admittedly derived by eyeballing the entire curve, but this is satisfactory for clinical application. The variation in ankle pressures in asymptomatic limbs helps to explain the range seen in patients with intermittent claudication and tissue threatening ischemia.

"Intermittent claudication" (Fig. 2) is defined as exertional muscle pain not associated with rest pain or ischemic ulceration on the skin. The wide distribution seen for the actual ankle pressure values (Fig. 2*A*) narrows when converted to a per cent of arm pressure (Fig. 2*B*). The majority of the readings fall in the 45 to 75 per cent of arm pressure range.

"Tissue-threatening ischemia": This group (Fig. 3) is designed to include the spectrum of patients from rest pain through refractory, non-healing ulcerations to frank cutaneous gangrene. A patient in this category may first present simple rest pain, whereas later the skin may become gangrenous. The ankle pressures may remain the same while the manifestation of the ischemia progresses. The difference seems to be in timing, not in pressure; consequently, the rest pain and the non-healing ulcer patients are considered together. The actual ankle blood pressure values (Fig. 3*A*) overlap the claudication group, however they cluster into a predictably lower range when converted to per cent of arm pressure. Most of these readings are in the 25 to 55 per cent zone.

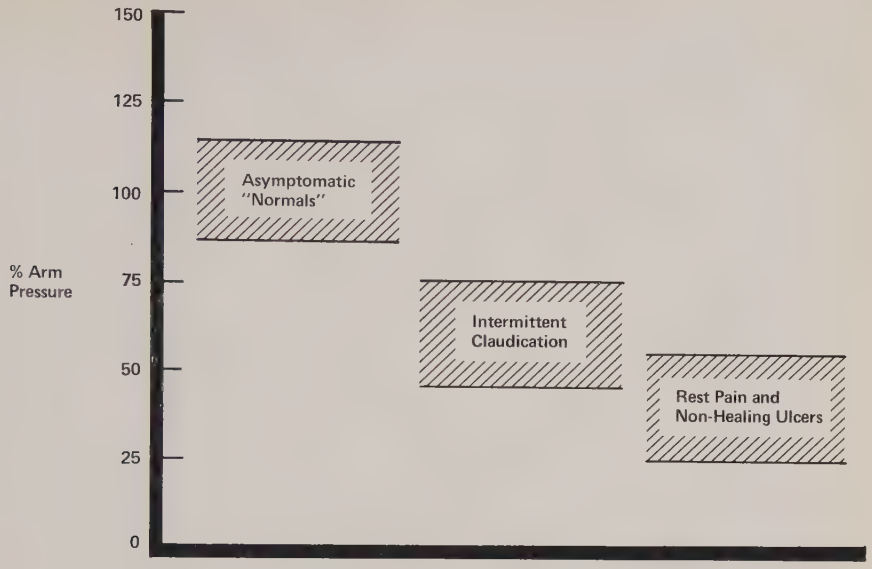

Figure 4. Summarizing ankle pressures as per cent of arm pressures.

These three categories, "asymptomatic normals," "intermittent claudication," and "tissue threatening ischemia," offer a sound clinical grouping of patients with occlusive vascular disease. The resting ankle blood pressure for each group falls into well-defined though slightly overlapping ranges, as summarized in Figure 4.

ANKLE PRESSURES AFTER EXERCISE

The person who experiences intermittent claudication presents a special challenge to the physician.[4, 5] The symptoms of exertional muscle pain emerge during exercise, yet the patient is examined at rest when he is free of discomfort. The claudication pain depends on the speed, elevation, and duration of walking, but very few patients can accurately equate these three components. As a result, the evaluation of intermittent claudication has always remained somewhat elusive.

Use of the ultrasound flow detector to determine the ankle blood pressure now offers a unique, functional test for patients with intermittent claudication.[13, 14, 17, 19] When a person walks, the calf and thigh muscles require a marked increase in blood supply. Normal vessels can accommodate this need, whereas narrowed or occluded vessels cannot. The exercising muscles take up or "steal" available blood at the expense of distal tissues. The foot and ankle become hypovolemic. Ankle pressure falls.[3, 10, 11, 12, 15, 17, 21]

We can utilize the fall in ankle pressure for exercise testing of the patient with intermittent claudication. Ankle pressures are first determined with the patient at rest; he then walks to the point of claudication and quickly reclines; ankle pressures are recorded for the next 30 minutes.

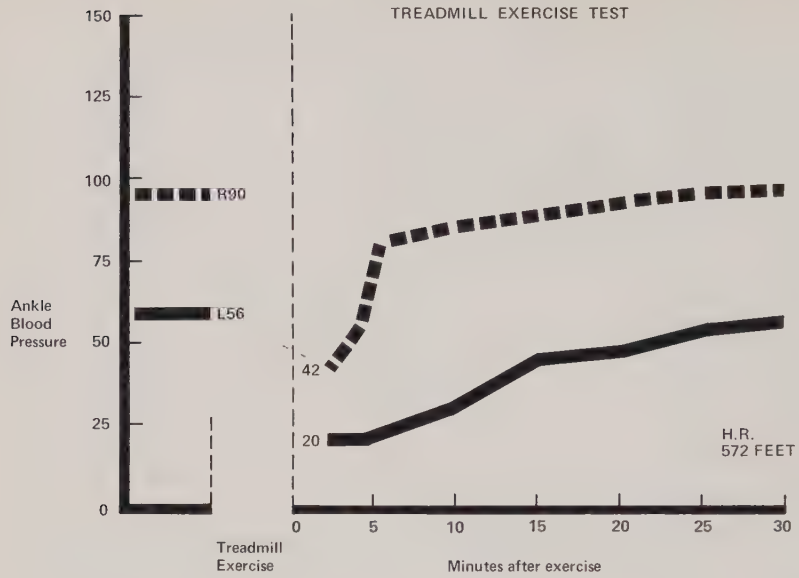

Figure 5. Sample ankle blood pressure response. H.R. intermittent claudication left calf.

The level of resting ankle pressure, the amount of fall with exercise, the recovery of ankle pressure, and the actual distance walked all constitute valuable indices of arterial insufficiency.[13, 14] This is illustrated in the following case.

H. R. described a 1 year background of intermittent claudication involving his left calf. He did not experience thigh or hip discomfort. He had no symptoms in the right leg. On examination he had a good femoral pulse on the left although no distal pulses. The femoral, popliteal, and posterior tibial pulses were all palpable on the right. Thus from the clinical aspect he had occlusion of the left superficial femoral artery. Using the Doppler ultrasound flow detector we recorded ankle pressures at 56 on the left and 90 on the right with simultaneous arm pressure of 155/85. He was able to walk 572 feet before claudication in the left calf forced him to stop. Immediately thereafter the Doppler detected the left ankle pressure at 20 with a right ankle pressure at 42. Ankle pressure on the left recovered gradually over the next 30 minutes, whereas the right ankle pressure quickly returned to resting level. This information has been graphed in Figure 5.

H. R.'s left ankle blood pressures at rest, post exercise, and through the recovery phase look typical for a patient with calf claudication. The right ankle pressures surprised us. Despite his lack of symptoms and the presence of a palpable posterior tibial pulse, he actually had an ankle pressure significantly below arm value (90 vs. 155). The ankle pressure fell markedly with exercise even though calf pain did not develop. Here the exercise testing documents the degree of vascular insufficiency in the symptomatic leg while uncovering simultaneous disease in the asymptomatic leg. Such information is invaluable in the proper evaluation and management of the patient with atherosclerotic occlusive disease.[4, 5, 13, 14, 19] We have seen similar patients in whom correction of unilateral claudication uncovered symptoms in the apparently normal leg.

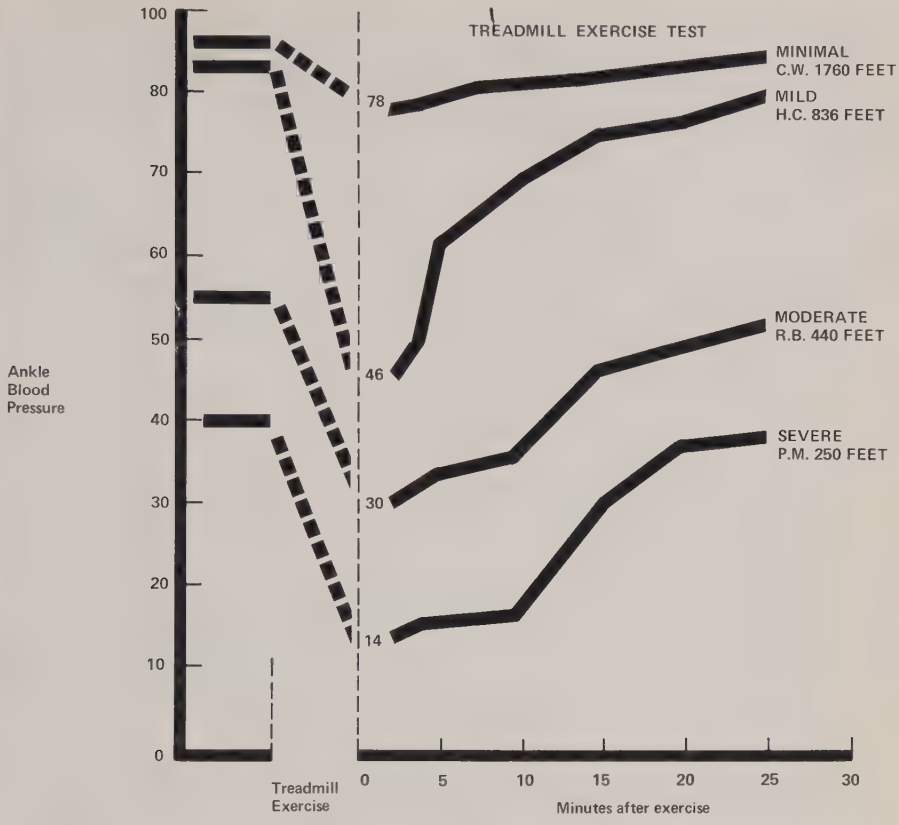

Figure 6. Ankle blood pressure patterns grouped by severity of intermittent claudication.

In Figure 6 we have assembled four typical ankle pressure responses that can be characterized as minimal, mild, moderate, and severe with respect to functional insufficiency.

1. *Minimal.* C. W. presented a 1 year history of intermittent claudication in the right calf despite a palpable posterior tibial pulse and the appearance of good nutrition to the toes. Right ankle pressure was heard at 92 with simultaneous arm reading of 130/78. Ankle pressure should approximate arm pressure and we see here a significant difference, despite the palpable pulse at the ankle level. This patient was able to walk 1760 feet before developing calf claudication. Immediately thereafter ankle pressure was 78. The resting ankle pressure of 92 and fall to 78 confirm the diagnosis of intermittent claudication due to vascular insufficiency. However, since he retained pulses and could walk a third of a mile, the claudication represented minimal involvement.

2. *Mild.* H. C. described an elusive 4 to 5 year background of progressive discomfort in his left leg, experienced as calf and thigh claudication. The left femoral pulse was reduced and carried an overlying bruit. There were no distal pulses. His arm pressure was 160/90 with a left ankle pressure of 88. When exercised to claudication he covered 836 feet while the ankle pressure dropped to 46.

3. *Moderate.* R. B. had only a 6 month background of intermittent claudication involving his right leg but the pain included calf, thigh, and hip components. The femoral and popliteal pulses felt markedly reduced. The dorsalis and posterior tibials were not palpable. His resting ankle pressure of 55 compared unfavorably with an arm reading of 142/86. He could walk only 440 feet before calf pain forced him to stop. Immediately thereafter ankle pressure came in at 30.

4. *Severe.* P. M. reported a 2 year background of claudication involving both calf muscles; the problem seemed slowly progressive with more recent exertional numbness across the toes of his right foot. He carried a long history of hypertension that persisted despite medical treatment; blood pressure 172 mm. Hg systolic, 100 diastolic. Ankle pressure of 40 fell to 14 when he walked just 250 feet to claudication pain. The ankle pressure remained under 30 for a full 15 minutes, indicating severe arterial insufficiency in this foot and ankle.

DISCUSSION

Numbers require no defense in clinical medicine. The hemogram, blood chemistries, and liver function studies are daily cornerstones of good practice. However, ankle pressures represent a new parameter and deserve discussion.[7, 19]

Arm blood pressures are valuable since they are easy to obtain, objective, recordable, reliable, and universally understood. What of ankle pressures? In our experience if one takes ankle blood pressures daily over 10 to 15 days, the recordings, expressed as percentage of simultaneous arm pressures, are consistent. Ankle blood pressures remain stable over 3 to 4 years in patients with no progression of their disease as judged by symptoms and physical examination. Deterioration of ankle pressure appears before clinical change. Ankle pressures are, therefore, a reliable indication of peripheral vascular disease.

These determinations also help identify the vascular component of symptoms that may arise from mixed arterial and venous disease, lumbar disc problems, arthritis, and diabetic neuropathies. We have not encountered patients with large vessel arterial disease as the cause for pain-paresthesia problems in the toes or foot when the ankle pressure is over 50 mm. Hg. We have not seen an ischemic ulcer on a toe heal if the ankle pressure is under 30 mm. Hg. By contrast, the atherosclerotic patient of 75 with a painful, infected paronychia involving the first toe stands an excellent chance for improvement with medical treatment if his pressures are 70 to 90 mm. Hg. Further, if a patient develops a nonhealing ulcer of the toe with normal ankle pressures, the physician must suspect the presence of a collagen vascular disease, neuropathy, or a systemic illness.

Resting ankle pressures provide the physician with an easy method for evaluating the patient with a peripheral vascular problem. The information offers a reliable supplement to descriptive symptoms and physical findings. Pressures are not a substitute for a careful history and physical examination.

What is the role of functional testing in peripheral vascular insufficiency? The sample cases taken from our experience document the numerical profile that one can obtain on patients with intermittent claudication using the ankle pressure response to exercise. The resting

ankle pressure, post-exercise pressure, recovery curve, and distance walked constitute new indices of arterial insufficiency. The ankle pressure response is surprisingly consistent for an individual patient. We have learned to "recognize" patients by their ankle pressure curves much as one can recognize a friend by the sound of his voice. Certain patients may walk 500 to 1000 feet despite a resting ankle pressure of 40 to 50, whereas others may cover only 200 to 300 feet with an ankle pressure that starts in the 75 to 90 range. But the individual remains constant to his own performance.

We now utilize this functional testing of the patient with intermittent claudication as an objective measure of arterial insufficiency that offers concrete supplement to traditional information.[13, 14] The patient's assessment of his walking ability and the presence or absence of distal pulses are not adequate criteria for judging any medical or surgical treatment program. Solid information is needed.[2, 19] For this reason we have employed the ankle response technique to evaluate the effectiveness of vasodilators in patients with intermittent claudication.[9] Patients undergoing reconstructive vascular surgery are tested preoperatively and at regular intervals following surgery.[7, 16, 19] We have seen deterioration in the ankle pressure curves 6 to 12 months before the appearance of symptoms. Every patient with worsening of the ankle pressure response to exercise has subsequently developed symptoms. Therefore we have confidence in the method and the message after performing more than 750 exercise studies.

SUMMARY

Ankle blood pressures now offer the clinician new information to aid his evaluation of the patient with a peripheral vascular problem. The pressures can be easily obtained using the Doppler ultrasound flow detector and a traditional blood pressure cuff.

This report shares our experience with resting and exercise ankle pressures in a variety of vascular disorders. It documents the insight that can be gained from applying the concept of ankle blood pressure to clinical problems in daily practice.

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Thoracic Outlet Syndrome

*Joseph W. Stayman, Jr., M.D.**

Thoracic outlet syndrome is now generally accepted as an entity that includes symptoms arising from compression of the neurovascular bundle of the shoulder girdle. The name was coined by Rob and Standeven[4] in 1958 and was elaborated upon by Clagett[1] in 1962. More recently Lord and Rosati[2, 3] and Roos and Owens[5, 6] have made significant contributions to the subject. As a result, we now have a clearer understanding regarding diagnosis and management of this problem.

In this paper we are presenting our experiences with 40 operated cases of thoracic outlet syndrome from the Chestnut Hill Hospital, Philadelphia, Pennsylvania.

Incidence

Thoracic outlet syndrome is probably more common than formerly estimated. This is largely due to the facts that more physicians are aware of the entity and that diagnostic methods are more accurate than in the past.

In our series the typical case is a young housewife with children. These women are active and are usually well developed muscularly. Thirty-three of our 40 cases were women. The average age for the series was 34 years. There was a definite history of trauma in 6 cases. The male patients were of heavy musculature in the shoulders, and had occupations that required the use of shoulder and neck muscles.

Approximately twice as many patients were seen and were clinically diagnosed as having thoracic outlet syndrome as were operated upon. These patients were placed on conservative therapy. Those who did not show improvement were evaluated for surgical treatment.

Anatomical Considerations

To understand the cause of symptoms in thoracic outlet syndrome, one must have a thorough knowledge of the anatomy involved. Figure 1 gives a sketch of the neurovascular structures as they cross the first rib, and their relationship to the anterior scalene muscle. For further ana-

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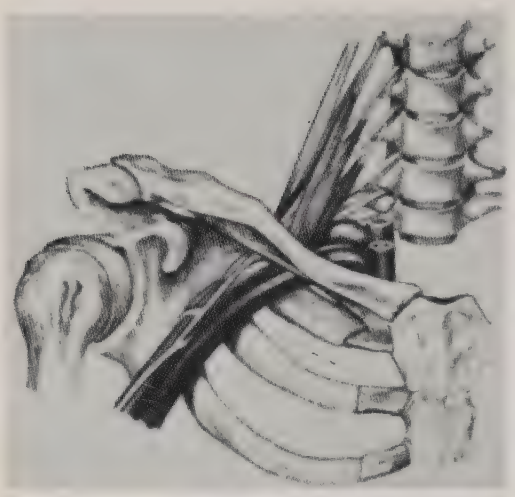

Figure 1. Regional anatomy. (*From* Roos, D. B., and Owens, J. C.: Arch. Surg., 93:71, 1966, by permission of The American Medical Association.)

tomic description, the reader is referred to Lord and Rosati's article in CIBA's *Clinical Symposia* and to the superb illustrations by Netter in the same article.[3]

One must keep in mind that developmental anomalies may produce symptoms, and that old injuries such as fractured clavicle can be significant. Cervical rib was present in 5 of our cases and it was resected together with the first rib. Probably only about 50 per cent of cervical ribs are symptomatic and one should be cautious in recommending surgery for these patients.

Symptoms

Symptoms may be vascular, neurologic, or a combination of both. Vascular symptoms may be venous or arterial. In our series 2 cases presented as venous occlusion with massive edema of the upper extremity. Most cases are a combination of arterial and neurologic symptoms. Arterial symptoms consist of pallor, temperature change, and interference with pulse. A positive Adson sign is usually present. Neurological symptoms are in the form of pain, anesthesia, and paresthesia. These findings, particularly pain, usually follow the course of the ulnar nerve. Symptoms are usually made worse by activity and by maneuvers that require abduction of the arms. Two of our patients were truck drivers and two were hairdressers.

Physical Examination

Physical examination usually reveals a well developed patient with good shoulder and neck musculature. There may be drooping of one or both shoulders or tilting of the head toward the affected side. Examination of the neck often reveals tense muscles, particularly in the scalene area. Examination of the involved extremity may reveal areas of anesthe-

sia and paresthesia, particularly along the course of the ulnar nerve. There may be signs of muscle atrophy, especially in the hand. Vascular involvement may reveal edema, color changes, temperature changes, and diminished or absent pulses. Because of the underlying anatomy, there is no one typical pattern of physical findings.

Diagnostic Studies

The following diagnostic studies are recommended and were carried out in nearly all cases prior to surgery in this series: chest x-ray, to rule out pulmonary disease, sulcus tumor, cervical ribs, etc; cervical spine, to rule out arthritis, fracture, anomalies, etc.; electromyogram, to locate level of nerve involvement and to rule out central nervous system disease; myelogram, to rule out cervical disc, cord lesions, and cervical spine deformity; arteriography, to locate level of arterial compression and to rule out other arterial diseases.

We feel that all of these studies are important and, if they are not carried out, serious disease may be overlooked. We also believe that arteriography is the most important of the studies. Compression or occlusion of the subclavian artery at the medial border of the first rib is an important diagnostic finding (Fig. 2).

In screening cases for surgery these diagnostic studies have exposed the following: cervical arthritis, 6 cases; central nervous system disease,

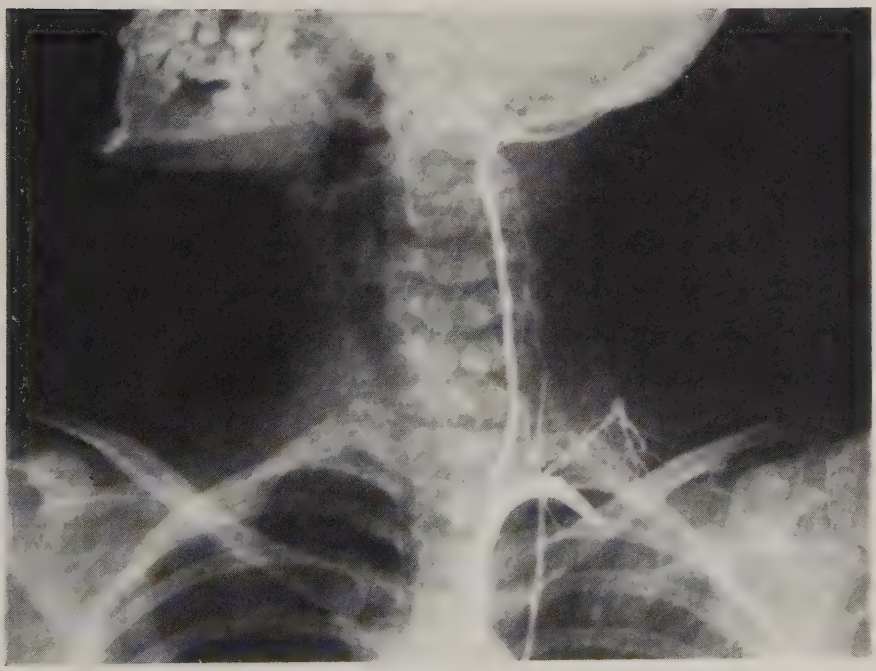

Figure 2. Arteriogram showing compression of the subclavian artery.

2 cases; pulmonary cyst, 1 case; carpal tunnel syndrome, 4 cases; pectoralis minor syndrome, 1 case; occlusion, subclavian artery (atherosclerosis), 4 cases; occlusion, brachial artery (atherosclerosis), 1 case. Had any of these cases been subjected to first rib resection, no benefit would have resulted.

Nonoperative Treatment

Nonoperative treatment consists of limitation of activity and physiotherapy. Our physiotherapy department has devised a course of exercises designed to elevate the shoulders and to correct posture. These exercises, together with limitation of activity, are often helpful. If there is no definite indication of recovery after 4 to 6 weeks of conservative therapy, the patient is evaluated for surgery.

Operative Treatment

The operative treatment for thoracic outlet syndrome consists of resection of the first rib. This may be accomplished by one of three approaches: (1) The cervical we feel is most difficult and do not recommend. (2) Posterior or first-stage thoracoplasty approach. We believe this approach affords the best exposure, particularly in the heavy patient or in the patient with cervical rib or vascular anomaly. (3) Axillary is the preferred approach and can be employed in most cases. It carries the least morbidity and the least disfigurement.

One half of our cases were operated upon by the posterior approach and one half by the axillary approach. In only 1 case was the cervical approach employed.

Complications

There was no mortality in this series. There were 2 cases of pneumothorax which responded to closed drainage. There was one case of partial brachial plexus paralysis , presumably resulting from retraction. This patient made a complete recovery in 6 weeks. There were 2 cases of wound seromas that responded to drainage. There was 1 case of partial wound dehiscence that required secondary closure.

Results

The overall results in this series of 40 cases are good. Only 4 cases are considered as poor results and were not improved by operation. The remainder of the cases are free of symptoms or are sufficiently asymptomatic to allow them to resume full activity without limitations.

An interesting observation was made in the cases with bilateral symptoms. Ten of the operated cases had bilateral symptoms. Following operation on the side with predominant symptoms, the contralateral side became asymptomatic except in three cases. Two of these cases have had bilateral surgery and the third case is being considered for operation. It is presumed that removal of one first rib may enlarge the thoracic outlet sufficiently to relieve pressure on the contralateral side.

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Arteriovenous Fistulas for Chronic Hemodialysis

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Repeated access to the peripheral circulation is an essential requisite for long term hemodialysis. The classical arteriovenous (A-V) shunt, as originally described by Quinton et al.,[5] permits easy access to the circulation, and is ideally suited for home dialysis. However, the complications of infection and thrombosis that accrue with arteriovenous shunts limit shunt life and, therefore, other means of access to the peripheral circulation have been needed. Since Brescia[1] described the use of an arteriovenous fistula for extracorporeal hemodialysis, we have found it to be the preferred method of providing access to the peripheral circulation for this purpose. The complications of thrombosis and infection, although not eliminated, are certainly encountered less frequently, and, therefore, the life of a surgically constructed arteriovenous fistula easily exceeds that of an arteriovenous shunt of the silastic Teflon variety. Arteriovenous fistulas are suitable for home dialysis since the veins are usually of sufficient size that venipuncture, even with large bore needles, can be performed by lay persons after an appropriate training period.

At the Thomas Jefferson University Hospital during the last 10 years, we have had an active hemodialysis program. Arteriovenous shunts were used exclusively from 1962 to 1967. Since that time all patients who are candidates for either home dialysis or transplantation have had arteriovenous fistulas constructed for dialysis if their forearm vessels would permit. Some patients have had previous arteriovenous shunts which had either become infected or thrombosed, and various types of arteriovenous fistulas have had to be constructed so that chronic hemodialysis could be continued.

It will be the purpose of this paper to present the various techniques that have been used for the construction of arteriovenous fistulas, circumstances that led to the choice of the various techniques, and the complications that have been encountered after their construction.

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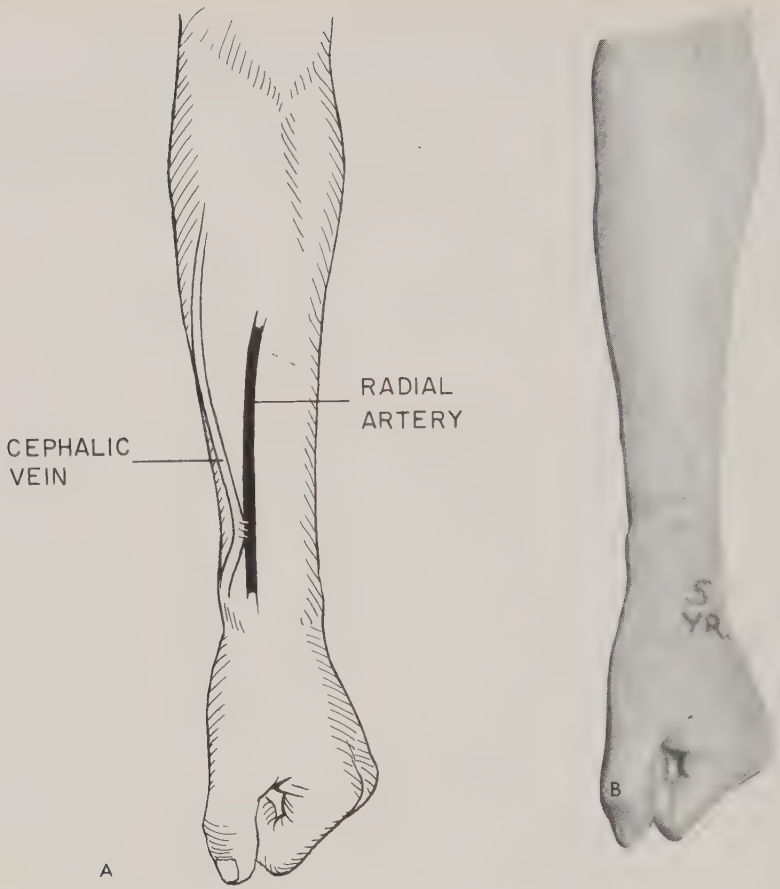

Figure 1. *A*, Distal radial-cephalic fistula. *B*, Actual fistula in use for 5 years. This is the most commonly constructed fistula.

Distal Forearm Fistula Between Radial Artery and Cephalic Vein (Fig. 1)

In a patient that presents for the first time for hemodialysis, where the forearm veins are readily visible and there is a good radial pulse, with a cephalic vein in close proximity to the radial artery, a side-to-side fistula between the cephalic vein and radial artery is our preferred technique. With the forearm fully exposed prior to preparing the arm for operation, a venous tourniquet is applied to the upper arm to make the forearm veins prominent. The course of the cephalic vein at the wrist is marked with a felt-tipped pen, as is that of the radial artery and the proposed line of the transverse skin incision.

The forearm and hand are then properly prepared with germicidal solution and draped with sterile stockinette and linen. A small opening is made in the stockinette over the proposed site of the incision and the skin infiltrated with a local anesthetic at that site. The ink marks on the skin

show the exact location of the vein and artery to be used for anastomosis, as well as their course, and this prevents accidental injury to these vessels while making the skin incision.

The skin incision is deepened to the plane of the adventitia of the cephalic vein and the deep fascia of the forearm, preserving only the sensory branch of the radial nerve to the thumb. The skin flaps are mobilized proximally and distally for a distance of about 3 cm. and meticulous hemostasis is secured with fine silk ligatures. The electrocautery is used only for skin bleeders since after the arteriovenous fistula is constructed, bleeding veins that have been electrocoagulated might rebleed as their venous pressure rises. The cephalic vein is mobilized over a distance of about five centimeters so that it is quite mobile and can be approximated to the vicinity of the radial artery without tension. A No. 0 chromic ligature which has been softened by soaking in sterile saline is used for traction on the vein and great care is taken to minimize handling of the vein with forceps. All tributaries of the vein are ligated with fine silk prior to their transection. An attempt is made to preserve an occasional large tributary which may communicate with veins on the dorsum of the hand. The vein commonly narrows after dissection, because of spasm, and at this time the vein wall is infiltrated with a jet spray of dilute papaverine solution delivered under pressure from a 5 ml. syringe with a 25-gauge needle. The vein will usually dilate maximally after a period of 5 to 10 minutes and be more suitable for anastomosis. During this period, the radial artery is mobilized.

The radial artery which lies deep to the forearm fascia is exposed by incising the overlying fascia along the course of the artery. It is uncommon to find any volar branches of the radial artery, but there are usually multiple fine lateral, medial, and dorsal branches of the vessel. The artery is first encircled with a moistened catgut ligature, and with gentle traction the branches become readily apparent. They are ligated in continuity with fine silk ligatures before transection. Failure to ligate them causes troublesome bleeding and hematoma formation in the wall of the artery.

When sufficient radial artery has been mobilized to permit its apposition to the cephalic vein without tension, the radial artery is also sprayed with a fine jet spray of dilute papaverine solution to reverse arterial spasm. The vessels are approximated, prior to their occlusion, with two stay sutures of 7–0 Tevdek placed in the adventitia of the vessels to maintain proper spatial relationships between the vessels and prevent their twisting or angulation. For the remainder of the operation we prefer to wear binocular operating loupes for magnification.

The adventitia is removed from the vessels at the site of the proposed anastomosis. The vessels are occluded proximally and distally with tourniquets fashioned from saline-softened No. 0 chromic catgut drawn through No. 240 polyethylene tubing. This has been found to produce minimal trauma to the vessels and minimize the risk of intimal damage. A linear incision is then made on the opposing portions of the arterial and venous walls with a Bistoury blade and completed with irridectomy scissors. Care is taken to limit the size of the arteriotomy and venotomy to 4 to 5 mm. An effort is made to avoid handling the edges of the arteriotomy and venotomy with instruments. The vessels are irrigated locally with

heparinized saline solution. We do not generally use systemic heparinization for construction of this arteriovenous fistula.

The fistula is then constructed by carefully approximating the vessels with a continuous running suture of No. 7–0 Tevdek interrupted at each end. It is important to take small full thickness bites of the vessel walls, keeping the bites close to the edge of each vessel and close together, so that approximately 16 to 20 stitches are used for a completed 5 mm. anastomosis. Traction on the suture line while sewing helps to identify the walls being sutured and prevents suturing opposing walls. Upon completion of the anastomosis, the occluding tourniquets are released first from the vein and then from the artery, and flow is established through the fistula. A thrill should be palpable over the cephalic vein at this time. The absence of a thrill suggests either a technical error or hypotension, and the source of this should be sought and corrected. Gentle pressure over the suture line will usually control leaks from needle holes. After suture line bleeding stops, the adventitia is carefully removed from all exposed portions of the cephalic vein. This permits the vein to dilate maximally and insures unimpeded flow through the fistula.

After hemostasis is secured, the subcutaneous tissue is approximated with fine catgut sutures and the skin is carefully closed. A light pressure dressing is applied. A loud continuous bruit should be readily audible through the dressing using the diaphragm of the stethoscope.

Blood pressure determinations are never permitted on the operated arm and venipunctures are permitted only when the arm is to be used for hemodialysis. In general, mild swelling of the forearm and hand occurs after construction of the fistula. This is attributed to an increase in lymph formation secondary to the elevated venous pressure, and usually subsides in 7 to 10 days. The use of the fistula for dialysis is usually postponed until after the swelling subsides, so that the swelling will not interfere with venipuncture. Premature use of the fistula before the swelling subsides has been attended by hematoma formation, accentuation of the swelling, and delay of the ultimate time when the fistula will be suitable for regular use.

We have constructed 70 such fistulas in 65 patients. The first fistula constructed over 5 years ago is still functioning and is used regularly for dialysis three times weekly. Eight fistulas have thrombosed from 1 to 8 months after construction and have had to be replaced by either a similar fistula in the opposite arm or one of the other fistulas to be described. The remaining fistulas are still functional 1 month to 66 months after construction. Fourteen patients have died of varied causes with their fistulas functioning up to 27 months after construction.

In 6 patients fistulas have been constructed in both arms where difficulty has been encountered in performing venipunctures in the original fistula due to swelling, so as to rest the arm with the original fistula. In no instance has symptomatic alteration of cardiodynamics been evident. We have found it necessary in a few patients to perform end-to-side rather than side-to-side radial cephalic fistulas. This has been primarily in patients with "pudgy" forearms, where the veins are not easily seen or palpated except at the wrist or dorsum of the hand. Diverting all flow from the radial artery into the cephalic vein is felt to produce maximal dilata-

tion of the forearm veins and enhance their use after several months. There have been no instances of so-called "ulnar artery steel" syndrome, and no instances of embolic or ischemic complications. Flow rates of 200 to 300 ml. per minute are usually obtained for dialysis when thin-walled 15-gauge needles and roller pumps are used. When the radial artery or cephalic vein in the forearm is occluded, then another type of arteriovenous fistula must be constructed for hemodialysis.

Distal Radial-Cephalic Fistula Where the Proximal Radial Artery is Obliterated (Fig. 2)

In three instances, where the proximal radial artery had previously been used for construction of an arteriovenous shunt, the distal radial artery was still patent, as evidenced by a palpable radial pulse at the wrist. The radial artery was being filled in a retrograde fashion by way of the palmar arch. The cephalic vein at the wrist was also patent and communicated freely with prominent veins on the dorsum of the hand. In

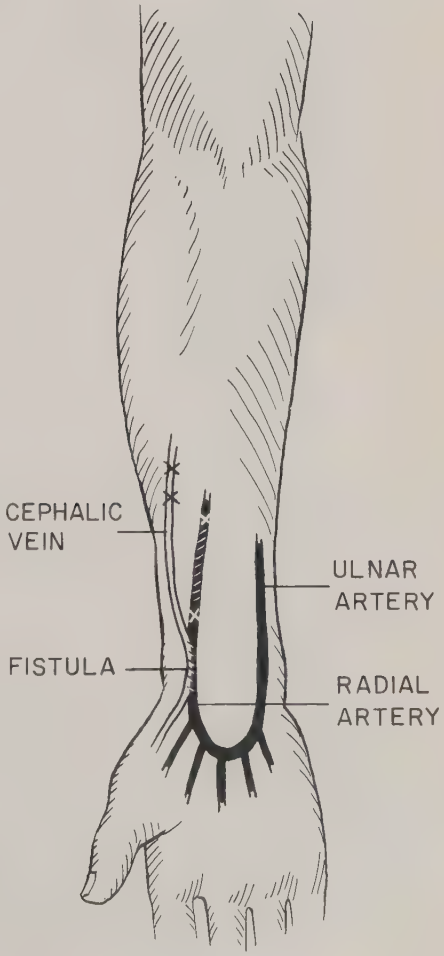

Figure 2. Distal radial-cephalic fistula where proximal radial artery and cephalic vein have been ligated as a result of former arteriovenous shunt insertion. Note that filling is retrograde through the palmar arch.

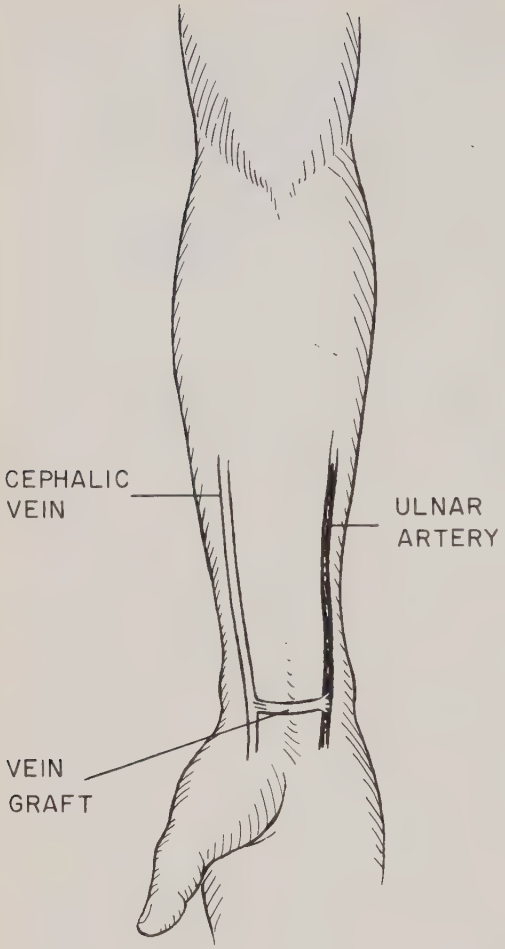

Figure 3. Ulnar artery-cephalic vein fistula; short segment of saphenous vein used to bridge gap between the artery and vein.

each of these instances a side-to-side fistula was constructed between the distal radial artery and the distal cephalic vein. These fistulas have functioned for 6 months, 18 months and 29 months after construction. One patient died 18 months after construction of the fistula with the fistula still functional at that time.

Ulnar Artery-Cephalic Vein Fistula (Fig. 3)

Where the radial artery is occluded but the forearm veins are well developed and the cephalic vein is still patent, an ulnar artery-cephalic vein fistula can be constructed by way of a short segment of saphenous vein. A segment of saphenous vein is removed from just above the ankle and interposed end-to-side from the ulnar artery to the cephalic vein or another suitable forearm vein in an end-to-side fashion. The same details of surgical technique are followed as with the radial-cephalic arteriovenous fistula, but the patient is systemically heparinized prior to occlusion of the ulnar artery. This prevents the development of thrombotic complica-

tions in the vessels of the hand, since in these patients, the ulnar artery is the major arterial inflow into the palmar arch. The heparin is reversed with an appropriate dose of protamine sulfate prior to the release of the occluding tourniquet on the ulnar artery. Two fistulas constructed in this fashion have functioned for 27 and 30 months.

Proximal Brachial Artery-Cephalic Vein Fistula (Fig. 4)

In patients with a paucity of forearm veins, but with a suitable cephalic vein above the elbow, the brachial artery is anastomosed to the

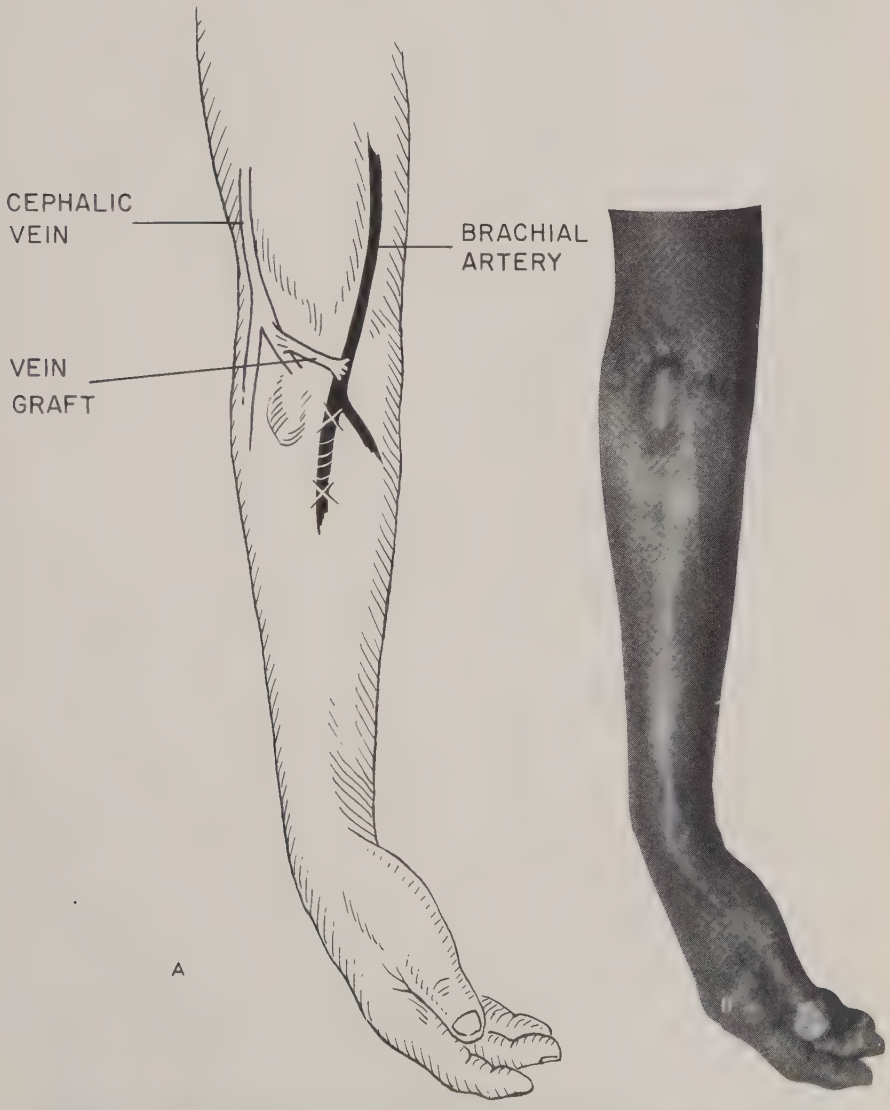

Figure 4. *A*, Proximal brachial artery-cephalic vein fistula. A short segment of saphenous vein is used to bridge the gap between artery and vein when they are not easily apposed. *B*, Actual fistula without saphenous vein segment, in use for 5 months.

cephalic vein by way of either the median antecubital vein or by way of the short segment of saphenous vein. The latter is used when the antecubital vein is either thrombosed or displaced laterally, making side-to-side apposition to the brachial artery either impossible or subject to considerable tension. Axillary block anesthesia is used for this type of fistula to prevent ischemic pain in the hand during the period of occlusion of the brachial artery. The patient is also systemically heparinized during the period of occlusion of the brachial artery. If the cephalic vein follows a superficial course in the brachium, so that it is readily visible beneath the skin, then further mobilization of the cephalic vein is unnecessary. However, if the cephalic vein follows a fairly deep course, so that a significant layer of fat is interposed between the vein and the overlying skin, then it is best to mobilize the vein from beneath the fat and displace it to a position just under the dermis. This can be accomplished through a series of small transverse incisions through the skin along the course of the vein. The vein is mobilized completely circumferentially throughout its course. The overlying fat is separated from the under side of the dermis along the course of the vein and then reapproximated, deep to the vein, with multiple sutures. This elevates the vein to its desired subdermal position, making it easily accessible for venipuncture. When the cephalic vein is quite small, it is best to delay mobilization of the vein for several weeks to permit the vein to dilate maximally in response to its increased blood flow. This makes mobilization much easier and minimizes the risk of injuring the vein during mobilization. We have constructed 6 fistulas of this type in 6 patients, and they are functioning from 2 to 6 months after their construction.

Saphenous Vein Loop Fistula (Fig. 5)

In patients with no suitable forearm veins, no suitable cephalic vein, but a normal saphenous vein and normal arterial circulation to the upper extremity, an arteriovenous fistula can be fashioned from a long segment of saphenous vein interposed as a loop between either the brachial artery or the stump of the proximal radial artery and any patent vein in the forearm or arm such as the median antecubital or brachial vein. This provides a long venous segment that will serve as both the arterial and venous conduits for hemodialysis. This operation is usually performed under general anesthesia. However, if the patient's condition does not permit, then local anesthesia can be used for the removal of the saphenous vein segment and axillary nerve block anesthesia can be used for construction of the arteriovenous fistula.

A segment of saphenous vein is mobilized from the groin to below the knee. All tributaries are ligated with fine silk. When the segment is removed, it is thoroughly irrigated with heparinized saline and filled under pressure with a bulldog clamp occluding its proximal end. This discloses any open tributaries which are then ligated or suture ligated with fine silk. All constricting adventitial bands are removed.

The patient is systemically heparinized prior to the arterial anastomosis. The vein segment is reversed and the distal end of the vein anastomosed end-to-side to the brachial artery or the stump of the radial artery. The vein segment is allowed to fill with arterial blood and its course is

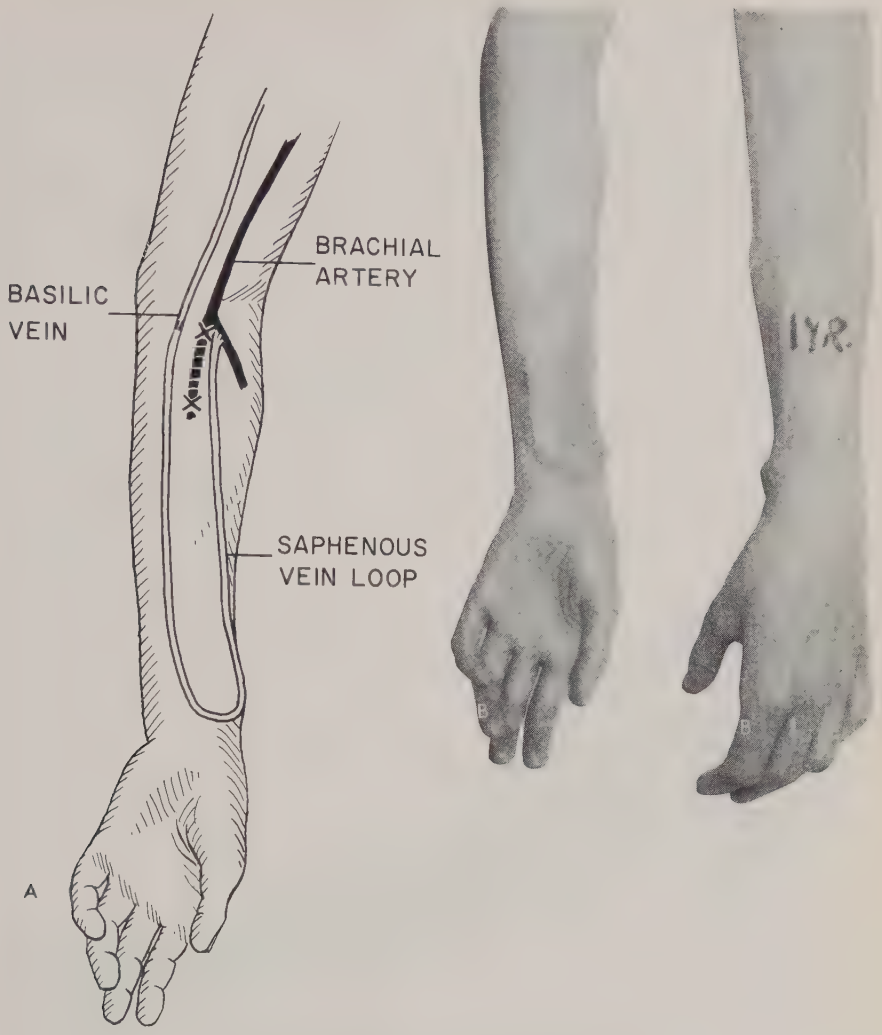

Figure 5. *A*, Saphenous vein loop fistula. *B*, Actual fistula, different views, constructed in a young woman after multiple shunt failures. Fistula in use for 12 months.

outlined on the surface of the forearm to its planned venous anastomosis. A gentle U-shaped loop is outlined to avoid kinking the vein. Through a series of short transverse skin incisions the vein segment is tunneled subcutaneously in the filled state to its venous terminus. Any excess saphenous vein is excised and an end-to-side anastomosis performed to a suitable vein. The heparin is reversed and flow is established through the saphenous vein. Hemostasis is secured and the wounds are closed. The forearm is immobilized in a posterior molded splint until the skin sutures are removed. When all swelling subsides, the vein is used for dialysis.

We have constructed 7 fistulas of this type in 7 patients. They have functioned for from 5 to 27 months after construction. Two thrombosed at 7 and 9 months after construction. Two patients died at 5 and 8 months after construction with the fistulas functioning at the time of death.

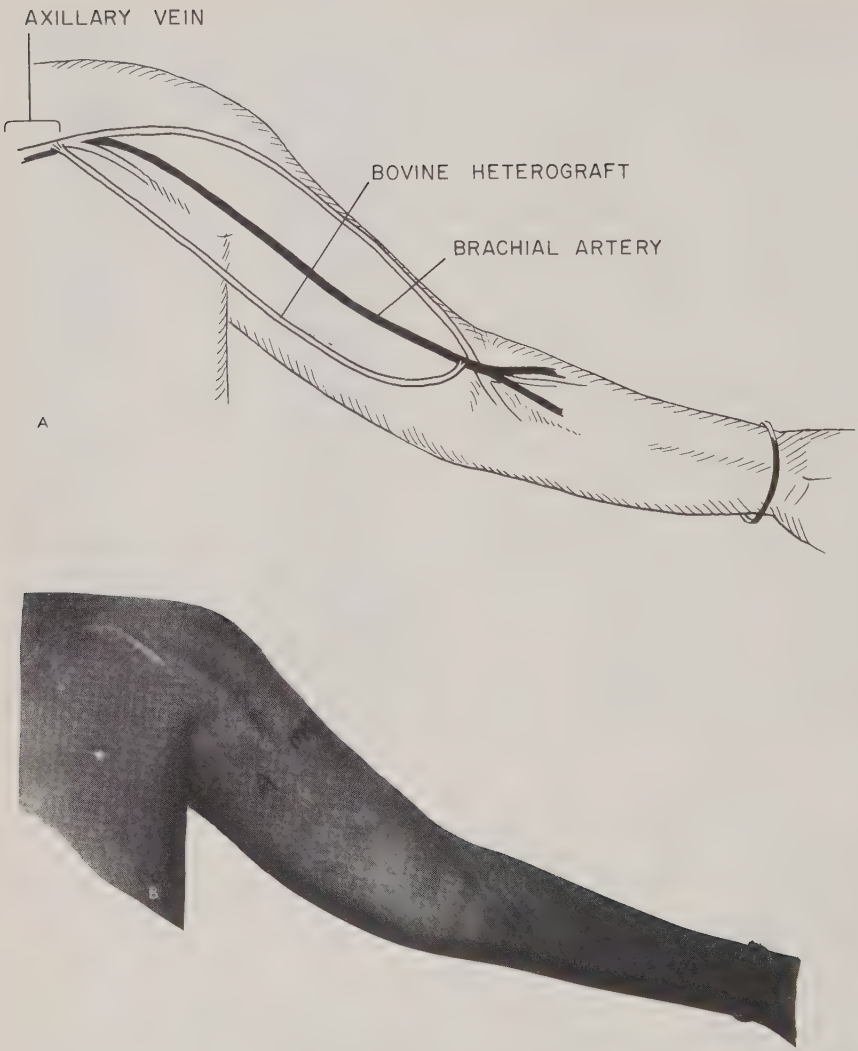

Figure 6. *A*, Bovine heterograft fistula from brachial artery to axillary vein. *B*, Actual fistula in use for 4 months in woman who has had multiple shunts over a period of 4 years.

Brachial Artery-Axillary Vein Fistula Using Bovine Heterograft[2] (Fig. 6)

In patients with no suitable forearm veins, cephalic veins, or saphenous veins, an arteriovenous fistula is constructed between the distal brachial artery and the proximal axillary vein using a bovine heterograft. The operation is carried out under either local or general anesthesia. The distal brachial artery is exposed just above the elbow and the axillary vein is exposed between the sternal and clavicular heads of the pectoralis major muscle. The pectoralis minor muscle is detached from the coracoid process and the axillary vein is readily identified. It can be partially occluded for appropriate anastomosis.

The patient is systemically heparinized and the distal anastomosis is made between the side of the brachial artery and the end of the bovine heterograft. The heterograft is allowed to fill with arterial blood and tunneled subcutaneously in the filled state in a straight line to its terminus at the axillary vein. Great care is taken to avoid twisting or kinking of the heterograft during this tunneling procedure. The heterograft is anastomosed end-to-side to the axillary vein. Flow is established through the heterograft and the heparin is reversed with protamine sulfate. Only one fistula of this type has been constructed in our series and it is functioning well after 5 months of dialysis.

COMPLICATIONS

Although complications occur with less frequency than with arteriovenous shunts, they do occur. When they occur, they threaten the life of the fistula. Infection has been an infrequent occurrence and usually responds to appropriate antibiotics and compressing. Thrombosis has occurred in 10 instances and has, on occasion, resulted in loss of the fistula. Focal venous aneurysms have occurred in three instances, requiring local aneurysmorrhaphy. There have been no instances of uncontrollable bleeding after dialysis requiring operative intervention. There have been no ischemic complications in the extremities with arteriovenous fistulas.

DISCUSSION

Arteriovenous shunts for hemodialysis usually have a limited life expectancy. They generally fail because of either infection or thrombosis. Since they must traverse the intact skin, they violate one of the body's natural barriers to infection. Despite the non-reactivity of the materials used for their construction, they are still foreign to the intima of blood vessels and can ultimately lead to subintimal proliferation and thrombosis. Arteriovenous fistulas used for hemodialysis do not require the use of "external hardware" except at the time of dialysis. The skin barrier is broken only during dialysis and foreign material need be indwelling in veins only during this same time. Therefore, the life of arteriovenous fistulas should be longer than that of arteriovenous shunts. This has been our experience in general and, therefore, we preferentially use arteriovenous fistulas in patients for long-term hemodialysis, and even those being prepared for renal transplantation. We have several patients whose original arteriovenous shunts have lasted for from 3 to 4 years, but these are exceptions rather than the rule. It is not at all uncommon for a distal radial cephalic arteriovenous fistula to last that long, and the first patient in whom we constructed an arteriovenous fistula 66 months ago, still undergoes dialysis 3 times weekly using the original fistula.

Dialysis flow rates in arteriovenous fistulas are comparable to those obtained with arteriovenous shunts. Infection can and does occur in arteriovenous fistulas and can threaten the survival of the fistula. This can

be avoided by meticulous antisepsis of the skin prior to venipuncture, and the application of a sterile dressing with a topical antibiotic ointment to the venipuncture site during and after dialysis. Thrombosis in arteriovenous fistulas usually results from traumatic venipuncture or repeated venipuncture at the same site. A careful training program of the person responsible for the venipuncture and selection of a different site for venipuncture for dialysis can minimize this complication. When thrombosis does occur, immediate thrombectomy will occasionally reestablish flow. However, in many instances the wall of the vein has been severely damaged, making restoration of flow impossible. Venous aneurysms usually result from repeated venipunctures at the same site. In 3 instances we have excised the aneurysm locally and reconstructed the vein wall to correct the problem. Arteriovenous fistulas are adaptable to home dialysis and 3 of our patients perform their own venipunctures.

In general, diverting arterial flow into existing forearm or arm veins produces the most favorable circumstances for long-term survival of an arteriovenous fistula. This allows venipunctures to be performed at disparate sites for dialysis and thus decreases the risk of thrombosis. When there are no veins available in the arm or forearm and a saphenous vein loop or bovine heterograft is used, the same vascular channel must be used repeatedly for dialysis. Despite varying the venipuncture site for each dialysis, a complication at any site jeopardizes the entire channel. In contrast, where a complication occurs in a forearm vein, where many veins are present and intercommunicate, the complication does not necessarily jeopardize the fistula. Therefore, we prefer to make maximum use of existing veins for constructing arteriovenous fistulas for dialysis before resorting to the use of a saphenous loop or bovine heterograft.

We have recently instituted single needle hemodialysis[3] in an effort to minimize the number of venipunctures necessary for each dialysis. It provides sufficient flow rates for efficient hemodialysis and should aid in increasing the life of fistulas, especially those of the saphenous loop and bovine heterograft variety.

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Selection and Management of Patients for Renal Transplantation

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Now that some 1200 renal allotransplants are being performed each year in the United States, transplantation has reached a level at which it is an important therapeutic reality as well as a continuing clinical experiment for chronic renal failure. The tenth report of the Human Renal Transplant Registry[3] analyzed data on 8332 kidney transplantations (5127 performed in the United States) reported to the Registry through 1971.

A well-functioning renal allotransplant provides the best rehabilitation of the patient with chronic renal failure. The achievement of a well-functioning renal transplant can be elusive in some patients since there is still much to be learned about the avoidance and treatment of immunologic rejection. Despite the great strides made in recent years, both in the knowledge of transplant immunity and in the practical management of patients, many aspects of renal transplantation and donor selection remain controversial at the present time. This point is brought home strikingly by the facts reported from the Transplant Registry. There has been a plateau in results of renal transplantation, with no significant overall improvement in graft function or patient survival for the past 5 years. Of the 466 cadaver kidney transplants reported from all centers for 1971, less than half (46 per cent) were functioning at 1 year despite reports of better results from major centers.

The following discussion is based on a personal experience with renal transplantation using both cadaver and family donors. An attempt is made to widen this experience by reference to the larger experience of well established transplantation centers in the United States and elsewhere.

SELECTION OF RECIPIENTS

Recipients for renal transplantation are pre-selected for renal dialysis under most circumstances. Occasionally a patient with progressive renal

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failure will be managed conservatively, but dialysis provides the best preoperative preparation of the patient. In general, selection of patients for chronic dialysis therapy requires that the patient be emotionally stable and realistic, with a relatively high level of intelligence and adaptability. It is most important that the prospective recipient have a realistic appraisal of his state of disease and also of the benefits that can be offered him by transplantation or chronic dialysis. We feel strongly that no patient should be talked into a transplant. On the contrary, many patients are overly optimistic and feel that a transplant will solve all problems in the future. This is particularly true in patients who have fairly severe complicating diseases associated with chronic renal failure which may not be reversible.

The availability of a family donor is of importance in that it obviates the problem of a long wait for a cadaver kidney and provides a better matched kidney with improved long-term survival. This is particularly true of course when a sibling with identical HL-A typing (an "A"-match) is available. In this case transplantation can offer the recipient a 90 to 95 per cent 2 year survival of the kidney with little loss after that period. The longer the wait for a cadaver kidney, the greater the chances of building up cytotoxic antibodies and of developing other problems associated with dialysis and chronic renal failure.

It is now apparent from a number of series that a high risk group of transplant recipients exists. These patients are those who have significant diabetes, cardiovascular disease, cerebrovascular disease, age over 50, or pre-existing immunity to the HL-A transplantation antigens. There have been reports of notable success with patients with these problems but the chance of success is less.

Diabetes has been considered a relative contraindication in most series; however, the University of Minnesota has now had a fairly extensive experience with diabetic patients receiving renal transplants and has found that these patients do surprisingly well with a relatively low incidence of recurrent diabetic glomerulosclerosis in the transplanted kidney.[11] Again, it should be stressed, particularly for those in the high risk group, that not all patients with chronic renal failure need a transplant if they can be maintained in a stable state and adapt their lives to the rigors of dialysis therapy. The mortality on dialysis is approximately 10 per cent per year.

The chronic anemia associated with renal failure allows patients to maintain a low hematocrit with relatively few clinical manifestations. However, these patients do need to be transfused when symptomatic. This must be done with frozen blood or carefully washed red cells to avoid transfusing white cells and platelets which will immunize them against HL-A antigens. The insidious development of cytotoxic antibodies is a very important factor in making it difficult to find donors for patients who have been on dialysis for some time. Recently, Opelz, Mickey, and Terasaki demonstrated that some patients develop protective enhancing antibodies after multiple transfusions.[13] However, in general, the fewer transfusions the less likely the production of cytotoxic antibodies which initiate hyperacute rejection of a transplant.

SELECTION OF DONOR

Related Living Donor

If the ideal donor, an HL-A identical sibling, is not available a haploidentical sibling, parent, or offspring can provide the second best type of match with excellent long-term survival for the kidney. Occasionally, a more remote family member, an uncle or a cousin, who demonstrates a relatively good HL-A match with the recipient is an excellent donor. All series have demonstrated an increased survival for a kidney from a related donor over that from a nonrelated donor, even when A-matched siblings are not considered. The San Francisco experience recently has been that cadaver kidneys matched for 2 to 3 antigens have survived as well as related grafts of equal HL-A grade.[8] However, most series have not been able to equal this experience.

The family donor should have no major health problems and should have a stable social and psychological history, good motivation, and a realistic appraisal of transplantation. There must be absence of coercion by either medical personnel or the immediate family. The gift of a kidney must be considered an extraordinary gift and one which should not be expected as a matter of course from a family member. We believe, moreover, that the physician talking with the family about transplantation should provide realistic data, both in terms of the nationwide experience and the local experience of transplant graft and patient survival. Rejection and its therapy and donor and recipient complications should be discussed along with the survival data of related versus nonrelated kidneys and the availability of cadaver donors. The criteria used for selection of a suitable related living donor are given in Table 1.

After voluntary donation has been obtained and a history has excluded inheritable renal disease or major medical problems, ABO typing and tissue typing are carried out. The donor, of course, must have an ABO type which is compatible with that of the recipient. The HL-A typing of the prospective family donor should provide at least haplotype identity, that is, identity of one antigen at both the first sub-locus and the second

Table 1. *Criteria for Selection of Living Donors*

1. Voluntary donation without coercion.
2. Stable social and psychological history.
3. Complete history and physical examination normal.
4. Absence of renal disease, hypertension, significant diabetes, transmittable neoplasm or systemic disease possibily jeopardizing the donor's kidney function in the future.
5. Normal CBC, EKG, chest x-ray, SMA-12, coagulation profile, STS.
6. Normal intravenous urogram.
7. Normal creatinine clearance.
8. Negative urine culture on two occasions; normal urinalysis.
9. Normal aortogram and renal arteriograms (major renal anomalies or more than 2 renal arteries may exclude donor).
10. Compatible ABO typing.
11. Compatible HL-A tissue typing (D match or better).
12. Negative crossmatch with recipient.

sub-locus. If the match is worse than this there may be no value of a related kidney over that of an unrelated kidney except availability.

The risk to the prospective living donor should be emphasized. There has been only one known death, in 1969, when a patient had died of a pulmonary embolism following a donor nephrectomy.[17] However, there are complications to this as there are to any major operation performed on a healthy individual. Penn's review[15] of 238 living donors in the Denver series showed 142 complications in 112 donors (47 per cent). However, half of these complications (71) were pulmonary, presumably related to the thoraco-abdominal approach employed at that center. It is important to note that within 18 days after unilateral nephrectomy a 40 per cent increase was found in the function of the remaining kidney.[9] We do not feel that an individual should be put at risk unless there is a high likelihood that there will be a successful outcome to the transplantation and that this would be more advantageous than using a cadaver kidney.

The aortogram and renal arteriogram in evaluation of a prospective donor are important in demonstrating anatomic variations and renal disease which are not apparent by other tests. Figure 1 is a renal arteriogram of a healthy 23 year old woman who was an A match for her brother. Although only one renal artery is seen here, it is apparent that this does not vascularize the entire kidney since the lower pole is not visualized. The IVP in Figure 2 shows a dilatation of the calyces and collecting system on the left side as opposed to the right. Study of the renal arteriogram, the aortogram, and IVP demonstrated an anomalous renal artery on each side which ran across the renal pelvis and vascu-

Figure 1. Left renal arteriogram in a prospective donor. The lower pole of the kidney is not vascularized by this artery.

Figure 2. Intravenous pyelogram in the same prospective donor. Note dilatation of calyces in left kidney.

larized the lower pole of each kidney. Although the second renal artery would pose only a minor anastomotic problem, the partial obstruction resulting from the anomalous position of the second artery precluded the use of this A-matched sister as a donor because of this potential renal problem. The patient was asymptomatic at this time. Fortunately for the prospective recipient, who was doing poorly after rejection of a cadaver graft, a brother volunteered. After an extensive family study of HL-A genotypes, it was proven that he also was an A match. The patient is doing extremely well with this transplant.

A recent experience with a related living donor kidney demonstrated to us that the venous drainage of the kidney should also be closely evaluated. Since the veins generally anastomose freely, one of several renal veins usually can be ligated. In this case, ligation of one of 3 renal veins compromised adequate perfusion of the kidney prior to implantation. It was necessary to open all 3 veins for adequate perfusion and then to anastomose the 3 in the recipient.

Cadaver Donors

Unrelated living donors have not been used in recent years. Although a potentially large source of good kidneys is being overlooked, a difficulty exists in assessing the motivations and emotional stability of such donors, although many of them are undoubtedly sincere in their humanitarian approach. Almost all surgeons decline to place a normal person under the slight risk of an operation for a recipient to whom he is not closely related. Furthermore, the results with such kidneys have not been better than cadaver kidneys.

The cadaver donor is generally a person who has suffered irreversible coma following severe brain trauma, cerebral vascular accident, or a non-

metastasizing primary brain tumor. The cadaver donor must have no systemic malignancy, no severe systemic infection, and no systemic disease involving the kidney such as hypertension, diabetes, or collagen disease. The kidneys should have normal function and no infection, as determined by creatinine, BUN, urinalysis, and urine culture. An IVP is desirable. The best kidneys are provided when there is good perfusion of the kidneys up to the time of removal. Signed permission by the next of kin for removal of kidneys for transplantation is necessary. In addition, almost all states have enacted a uniform anatomic gift act allowing persons to will their organs after death.

The criteria for brain death as proposed by the Harvard Ad Hoc Committee[1] have established the diagnosis of death on criteria other than cessation of heart beat. These criteria have been shown to be valid in identifying with certainty patients who will not survive profound coma.[4, 10]

Death must be determined by a physician who is not a member of the transplant team but who is concerned solely with the welfare of the prospective donor. Some medical centers have established a committee for this purpose which usually includes neurologists, neurosurgeons, and anesthesiologists.

The availability for the cadaver kidney of pulsatile perfusion using oxygenated plasma confers the distinct advantages of objective evaluation of kidneys removed under less than optimal conditions, longer preservation times, and more elective scheduling of transplant operations. We have found simple gravity perfusion of a kidney with cold Ringer's lactate with added heparin and procaine or with Collins solution permits storage at 5° C for 10 hours or more without significant acute tubular necrosis. This time allowance permits adequate patient preparation and laboratory studies but does require much emergency scheduling.

DONOR-RECIPIENT MATCHING

Two major histocompatibility systems in man are well established: the ABO blood groups and the HL-A antigens. There is recent evidence that there also may be outside the HL-A chromosomal region a histocompatibility region which determines mixed leukocyte culture reactivity. At the present time only ABO and HL-A antigens are determinable by serologic methods. The role of ABO antigens is well established: failure to have donor-recipient ABO compatibility results in extremely high incidence of hyperacute rejection. HL-A antigens have proven to be of greatest value in selection of the most compatible family member, particularly of the most compatible sibling. A sibling may be identical for the four HL-A antigens, identical for two (haplo-identical) or be mismatched for each of the four HL-A antigens. In the sibling group, HL-A antigen typing has shown good correlation with the transplant results.[5]

In cadaver selection, HL-A tissue typing has not lived up to early expectations because it has been difficult to show in detail good correlation between the number of antigens matched and the outcome of transplantation, with the possible exception of A-matched cadaver grafts.[12] Dausset and co-workers have shown an excellent correlation between HL-A

tissue typing and outcome of cadaver grafts by taking into account cross reactions and unknown antigens.[7] Other investigators have not been able to show as good a correlation between a specific mismatch for 1, 2, or 3 antigens and the outcome of cadaver transplantation. The better results obtained with related donors as opposed to cadaver donors even when the same HL-A matching is present suggests that there may be other histocompatibility systems, in particular a locus determining cellular immunity as manifest in mixed leukocyte culture reactivity. In general, the lack of correlation has been due to the very good course of some very bad matches. Now that there is better appreciation of the role of pre-existing immunity as demonstrated by either cytotoxic or blocking (enhancing) antibodies, better correlation with HL-A typing of cadaver transplantation with HL-A typing may be achieved.

What then is the role of tissue typing for cadaver transplantation? At the present time, it does not appear that the correlation between tissue matching and the outcome of a cadaver graft is close enough to withhold a transplant from a patient because of 1, 2, or 3 antigen mismatches. What appears the better course now is obtaining the best possible match within the local or regional recipient pool for a particular cadaver kidney.

The direct crossmatch between the donor cells and the recipient's serum is the single most important laboratory test for discovering pre-existing immunity of the recipient for donor tissue. The presence of circulating antibodies to donor cells is associated with an extemely high incidence of hyperacute rejection. This crossmatch must be done with exceedingly great care in patients who have been on dialysis for a prolonged period of time or who have had multiple transfusions. We have found that the extended crossmatch methods outlined in Table 2 have provided us with a clearer idea of a patient's state of immunity and have prevented transplantation in the presence of pre-existing immunity, and thus have prevented hyperacute loss of the kidney.[6]

The studies of Patel[14] and Terasaki[19] have indicated that pre-existing serologic immunity may act in a more subtle fashion by seriously impairing the long-term function as well as causing hyperacute rejection. Low levels of pre-existing immunity thus may manifest themselves only as longer term rejection. Crossmatching of prospective recipients with cells of random individuals picks up cytotoxic immunity to HL-A antigens. Pa-

Table 2. *Extended Crossmatch Procedures for Prospective Transplant Recipients*

1. Crossmatch profile of 6 wells with 2 dilutions and 3 concentrations.
2. Crossmatch against "random" lymphocytes to detect presence, prevalence, and specificity of any cytotoxicity.
3. Donor cells crossmatch against recipient's sera of several dates, especially dates of high incidence of random cytotoxicity.
4. Single and doubled incubation times.
5. New serum sample drawn routinely each month.
6. Monthly new serum samples sent to donor centers and regional organ sharing programs.
7. The final crossmatch done 24 to 48 hours prior to transplantation with new serum samples.

tients with such cytotoxicity have been shown to constitute a high risk group for transplantation, even when the standard crossmatch with the donor is negative.[19]

PREPARATION OF THE RECIPIENT FOR SURGERY

In most patients, splenectomy, bilateral nephrectomy, and appendectomy are performed. This is planned for approximately 6 weeks prior to scheduled transplantation to allow full recovery by the time of transplantation. The role of nephrectomy in preparation for transplantation is not completely established. We believe that bilateral nephrectomy is helpful under the following circumstances: (1) when hypertension is present. (2) when the kidneys are symptomatic because of very large size or bleeding as in polycystic disease; (3) when the kidneys may be an actual or potential site of infection; (4) when the primary disease is glomerulonephritis. In the last case, nephrectomy may remove a constant stimulus for the production of anti-glomerular and anti-kidney antibodies. When transplantation is performed later under immunosuppressive therapy there may be less likelihood of autoimmune damage to the kidneys.

Bilateral nephrectomy in a patient whose kidneys produce 500 ml. or more of watery urine per day imposes further fluid restriction preoperatively but postoperatively allows more accurate appraisal of renal function since the urine output is solely from the transplant.

Splenectomy is somewhat more controversial. Splenectomy clinically appears to diminish the toxic effects of the immunosuppressants on white cells and platelets and allows larger doses to be used more safely. Pierce and Hume[16] have presented evidence that splenectomy diminishes rejection in second transplants. Splenectomy may also permit longer red cell survival in the anemia of chronic renal failure.

Our current practice is to perform these procedures at a single operation through a transperitoneal approach approximately 6 weeks before transplantation. A thorough exploration of the abdominal cavity is done to rule out occult peptic ulceration, Meckel's diverticulum, malignancy, sites of infection, or sources of gastrointestinal hemorrhage. An appendectomy is performed to obviate a source of confusion with rejection of a right lower quadrant kidney.

Prior to transplantation the lower urinary tract is thoroughly evaluated to make sure that it is neurologically and anatomically normal without obstruction. This evaluation is done by cystoscopy, voiding cystogram, and retrograde pyelography. A complete eye examination is carried out to rule out glaucoma or early cataracts because of the possibility of exacerbation by long-term steroids. As mentioned previously, ABO typing, HL-A typing, and crossmatching both to random individuals for the presence of cytotoxic antibodies to HL-A antigens and to the specific donor are carried out.

Parathyroid status is evaluated and parathyroidectomy considered if hyperparathyroidism is evident and transplantation distant. In general, hyperparathyroidism responds to transplantation. Hepatitis-associated antigen is determined in dialysis patients because of the risk to the pa-

tient placed on steroids as well as to other patients and those taking care of him. X-ray of the femoral heads is useful for comparison later in case the question arises of aseptic necrosis with steroid therapy. Tuberculin testing is done. If the result is positive or there is a positive history of tuberculosis, INH is given concomitantly with the immunosuppressive drugs. Histoplasmin and coccidioidin skin tests are also carried out in order to determine the patient's prior exposure to these mycoses. If the patient is still producing urine, urinalysis and culture are performed. If the patient has undergone nephrectomy, the bladder is irrigated with sterile saline and cultured. One per cent neomycin solution is introduced into the bladder at the end of the catheterization.

Full informed consent is obtained. If the patient is a male he is informed that one spermatic cord will be ligated and divided to provide adequate access to the retroperitoneal space. Psychiatric evaluation is carried out if indicated. Shunts and fistulas are carefully checked to make sure that they are not a site of infection which could be disastrous while the patient is on high doses of immunosuppressants. Other sites of possible infection must be carefully checked and cultured.

After preliminary studies and procedures have been carried out the patient is admitted for transplantation. Dialysis is performed on the preceding day with electrolytes obtained after dialysis. Particular attention is paid to the potassium levels since these can rise precipitously with profound effect on the cardiac rhythm. A further determination of potassium and other electrolytes is obtained in the morning prior to operation since the potassium appears to rise with emotional stress alone.

As with any preoperative patient a chest x-ray, electrocardiogram, creatinine, BUN, transaminase, alkaline phosphatase, calcium, phosphorus, and blood sugar are obtained. Although a low hematocrit is well tolerated in patients with the chronic anemia of renal failure, we transfuse to a level of 25 for adequate oxygenation with inhalation anesthesia. Transfusions are carried out using either frozen blood or red cells carefully washed by a continuous flow method. Other methods of producing "buffy-coat poor blood" have been shown to contain sufficient white cells and platelets to sensitize the patient to transplantation antigens. The "dry" weight of the patient is obtained so that subsequent weight gain will indicate fluid accumulation. The matching between the donor and the recipient is again rechecked and a careful crossmatch is carried out in depth 24 to 48 hours prior to transplantation. Urine, throat, and sputum are recultured. The shunt site is cultured. An elective transplant is carefully scheduled ahead of time with the operating room so that there are 2 adjoining rooms available for the related living donor and the recipient at the earliest part of the day. Skin preparation is carried out from the nipples to knees including the perineum. The following drugs and supplies are obtained for the patient in the operating room: azathioprine, methylprednisolone, antibiotics, mannitol, intravenous solution of 5 per cent dextrose and half normal saline, kidney irrigation catheters, chilled Ringer's lactate, frozen Ringer's lactate for slush, and washed fresh red cells or frozen red cells for transfusion. Full surgical preparation of the skin is done for insertion of all intravenous needles and catheters.

THE OPERATION

Our operative approach is essentially that which is well described in the classic book by Starzl.[18] Therefore we will touch only on significant details of that operative procedure. The patient is placed on a cardiac monitor because of possible difficulties with hypotension, hyperkalemia, and electrolyte imbalance. Anesthesia is carried out using a relatively light inhalation anesthesia, essentially nitrous oxide and oxygen, with curare for muscle relaxation if needed. Cyclopropane or ether or halothane appears to be a suitable agent.

The patient is placed on the operating room table in a supine position and a folded sheet is placed under the right hip to slightly elevate that side. We prefer placing the kidney in the right pelvic area since the vessels appear to be more easily accessible. Preparation of the skin is carried out with povidone-iodine: first the lower thorax and abdomen are prepared and temporarily covered. The perineum and genitalia are prepared separately and draped with a sterile drape. A Silastic Foley catheter is then inserted using as large a size as will comfortably fit into the urethra. The larger size is useful to remove postoperative clots. The Foley is clamped and the patient is then fully draped with plastic and sterile cloth drapes. The gowns preferred are those used with waterproof inserts to prevent a break in the sterile technique due to soaking of the gown, particularly during the ureteroneocystostomy.

A long incision is made from the midline to above the iliac crest on the right with incision rather than blunt dissection of the muscles. The spermatic cord is doubly ligated and divided. Although there is frequently some postoperative swelling of the testicle on that side, this has proved only a minor problem. The peritoneum is reflected cephalad and access gained to the retroperitoneal area. The areolar tissue over the vessels is carefully dissected and ligated to avoid lymphocele and minor hemorrhage. The external iliac vein is dissected up to the crossing over of the internal iliac artery, which itself is then carefully dissected down to its first 2 branches.

Umbilical tapes are placed around the vein and around the origin of the artery. After dissection has been carried out to this extent, a circular Smith retractor is used to maintain good access to the operative field without overtaxing the assistants. Deep dissection of the internal iliac artery down to the secondary branches can be difficult. The distal vessels are doubly ligated or ligated and clipped. Occasionally the internal iliac artery will be markedly arteriosclerotic in an older male. Care is taken not to strip the adventitia unnecessarily from the artery or to dissect within the media. Arteriosclerotic plaques are usually removed only directly at the suture line.

Close coordination is carried out with the operative team in the donor room in elective transplantation. The donor nephrectomy is generally done through a flank incision. The donor has been well hydrated with intravenous fluids through the night; a Foley catheter is placed at the operating table, and mannitol is given during the operation. The ureter is dissected with its adventitia intact down to the pelvic brim and divided. The renal vessels are dissected to the aorta and vena cava. After excellent

urine production is obtained (1 ml. per min. or better) and the recipient team is ready, the vessels are then divided. The kidney is immediately placed in ice cold solution and carried to the perfusion table which is set up in the recipient room. This perfusion table has a waterproof covering, large basin and smaller round basins which are filled with frozen lactated Ringer's slush. Fine scissors, vascular forceps, ligatures, and mosquito clamps are on this table under an excellent light source. Ice cold Ringer's lactate containing 5000 to 10,000 units of heparin per liter has previously been set up with sterile intravenous tubing. Small polyethylene catheters are used to irrigate the kidney and they are placed gently within the lumen of the artery. Vascular clamps are used to hold these in place while perfusion fluid is run through. All arteries must be perfused or there may be thrombosis and infarction. Care must be taken especially when there are major branches which come off immediately from the major renal artery. If there are two major renal arteries both of these must be perfused. Perfusion can be generally considered successful when the effluent is not bloody and the kidney is ice cold, pale, and firm in all areas. The vessels are carefully dissected and trimmed. Usually accessory renal veins can be ligated without problems. The kidney is brought to the operating table in the ice cold basin.

The internal iliac artery is clamped at its origin and doubly ligated and divided distally at its branches. The external iliac vein is then clamped proximally and distally with vascular clamps. An elliptical window the size of the renal vein is cut with fine scissors for the venous anastomosis. Guy sutures of 5–0 or 6–0 Dacron are then taken between the renal vein and the elliptical window in the external iliac vein. A lateral guy suture is placed to ensure that the two walls are not inadvertently sutured. The vein is flushed out with dilute heparin solution by a flexible catheter. The medial aspect of the vein is first sutured and then the lateral with a continuous over and over suture, the guy suture is tied down and oversewn. The vascular clamp at the origin of the internal iliac artery is released to flush the artery and reapplied. The distal artery is flushed with a dilute heparin solution. Two double ended sutures of 6–0 Dacron are placed at 180° and ligated. The arterial anastomosis is performed with a running technique on each side. The total time for the vascular anastomoses should be less than 1 hour. During this period the kidney is kept cold by irrigation with Ringer's lactate solution and by ice cold laparotomy pads. Once the vascular anastomoses are completed, first the vein clamps are removed, revealing any minor leakage at the venous suture line, and then the arterial clamp. Frequently there are one or two small areas of leakage in the artery; finger pressure is kept on these. If there is no response to pressure in 5 or 10 minutes these may be sutured. It is unwise to clamp the vessels completely at any time after completion of the anastomosis and removal of the clamps.

The present schedule of immunosuppression employed is an intravenous bolus of methylprednisolone (125 mg.) preoperatively and 375 mg. at operation. The azathioprine is given in intravenous solution at a dose of 4 mg. per kg., with the greater part of this given after revascularization. For elective operations azathioprine and methylprednisolone are given on the two days prior to transplantation in dosages of 2 mg. per kg.

and 80 mg. respectively. We have found it most advantageous to have a nephrologist in the operating room to manage these aspects of patient care while the attention of the surgical team is directed elsewhere. His presence at operation also gives the nephrologist a better appreciation of surgical technique and of any problems which may arise. After the vascular anastomosis the patient may be primed with 12.5 to 50 gm. of mannitol. We have not used other diuretic agents at this point in the patient's course. Usually, even in cadaver kidneys we have had immediate urine production at the operating table. This, in the cadaver group, depends very much upon the state of perfusion and "quality" of the cadaver kidney harvested.

The ureteroneocystostomy is next undertaken. The Foley catheter is sought underneath the layer of drapes and the bladder is filled with saline. The adventitia is cleaned gently off the dome of the bladder where a longitudinal incision is made. Stay sutures are taken in the wall of the bladder and incision is made in the lateral bladder wall above the right ureteral orifice. The distal ureter is then brought through the bladder wall with great care to make sure it is not twisted. This can be most readily determined by the course of the ureteral vessels. We employ the submucosal tunnel technique although this may not be necessary to prevent reflux.[20] Excess ureter is then cut off as the ureter is spatulated. The distal portion is evaginated with a single 5–0 catgut suture and the remainder of the ellipse of the ureter is sutured with interrupted sutures. Two sutures are taken in the outside wall between the ureter and the bladder. A small No. 8 French catheter is passed up the ureteral orifice to make sure there is no obstruction. The bladder is irrigated of all clots and it is then closed in 3 layers, with the outer layer being interrupted Dacron. In most cases, the ureter should be producing urine at the time of closure, particularly if the graft is from a related living donor. The Foley catheter is irrigated, connected to gravity drainage and watched carefully for urine production. The large Smith retractor is then removed. After irrigation of the wound and observation for hemostasis the wound is closed in layers with interrupted silk sutures.

POSTOPERATIVE CARE

At the end of the procedure the patient is usually awake or lightly asleep. He is taken to a private room with a specially assigned nurse. Protective isolation procedures are employed consisting of hand washing, masks, and gown; gloves are used for handling the patient's wound or direct patient contact. Vital signs are checked every 15 minutes until the patient is stable and then checked every 1 hour thereafter. Temperature is checked by rectal probe. Blood pressure is obtained in the arm without a shunt or fistula. Postoperatively, since there is a high incidence of thrombosis of arteriovenous shunts, these should be checked every 1 hour as well. Intake and output is checked every hour with note being made of the flow, rate, and character of the urine, which may be bloody in the immediate postoperative period. One of the main problems to be looked for is the presence of clots within the tubing; failure of the urine

flow must be reported by the nurse to the physicians immediately so that the catheter can be irrigated.

We maintain the patient with the head of the bed elevated at 20 degrees and foot at 30 degrees in order to provide better respiration and better venous drainage of the legs. Elastic stockings are employed in the patient and he is urged to dorsiflex his ankles. We have employed a prophylactic antibiotic in most of our cases, using cephalothin or a penicillinase-resistant penicillin for the first 3 days starting at operation. A sound argument could be made for not employing any prophylactic antibiotics except for definite breaks in sterile technique or specific infections.

Postoperative laboratory studies are obtained including electrolytes, BUN, blood sugar, calcium, phosphorus, alkaline phosphatase, SGOT, uric acid, creatinine, and bilirubin. A complete blood count is obtained daily. Quantitative urine cultures and sensitivities are done each day and 24 hour urine specimens are obtained for creatinine, protein, sodium, and osmolality.

The postoperative immunosuppressant dosage schedule we have used has been the same for both cadaver and related living donor kidneys. It is modified in the case of an A-matched sibling. Postoperatively, azathioprine is given first intravenously and then orally in dosages of 3 mg. per kg. on the first postoperative day, then 2 mg. per kg. on day 2 and each day thereafter, provided the white count is maintained at approximately 5000. Methylprednisolone initially given in dosage of 500 mg. on the day of operation is continued in a dosage of 125 mg. every 6 hours for 3 doses and then 80 mg. per day in 2 divided doses for 7 to 10 days with drop in dosage every 7 to 10 days to a maintenance level of 16 to 32 mg. per day. Irradiation of the transplant with 150 rads is performed on days 1, 3, and 5. Antilymphocyte globulin has been shown to be an effective immunosuppressant. However, we have not used it because we have not been able to obtain a sufficient supply of a potent and safe batch of antilymphocyte globulin.

The patient's diet is resumed as soon as feasible, beginning with skim milk and advancing to a modified ulcer diet. The recipient is usually able to take a full diet within 1 to 2 days after transplantation. In addition to the diet, antacids are given between meals and at bed time as a prophylactic measure against ulcer formation while the patient is on high doses of steroids. The patient is out of bed and walking by the first postoperative day and daily weighings are resumed at this point. The patient is allowed to sit in a lounge chair by the fourth postoperative day but we try to keep the patient out of a straight back chair for the first week because of the position of the transplanted kidney.

In following a transplant patient in the immediate postoperative period we have found most helpful the flow sheet provided by the ACS/NIH Kidney Registry which is posted outside the patient's room and also a flow sheet which is carried in a looseleaf notebook for instant access to laboratory values. It is helpful to have one member of the transplant team assigned to keep close watch over the patient's values day by day and record them so they are available to all. Frequently, the changes from day to day are most important in determining renal function and the patient's

overall status. The serum creatinine is perhaps the single most important laboratory value and is a much easier value to obtain than the creatinine clearance which tends to vary considerably due to the vagaries of 24 hour urine collection even when it is closely supervised. Serum glucose can rise considerably under the influence of high levels of steroids particularly during the period of a rejection episode. Urine cultures are followed daily in order to pick up an infection. Initially, we left in the Foley catheters up to 10 days, which resulted in a high incidence of mild urinary infections. We now would not recommend leaving in a Foley catheter beyond 2 days except for very definite indications, since it does not appear to be necessary either to decompress the bladder or to aid in following the urine production postoperatively.

Prolonged follow-up of patients with renal transplantation must be carried out after discharge from the hospital. Rejection, infection, renal dysfunction, and cancer must be looked for. Patients are followed twice a week for 3 months, every week for an additional 3 months, then once or twice a month. The patient must be alerted to inform his physicians and surgeons of any fever or illness and to return to the hospital for any medical problems so that he can be evaluated.

Infection either with or without rejection remains the most common complication and cause of death in the transplanted patient. The Ninth Report of the Transplant Registry lists sepsis as a sole or contributing cause of death in 48 per cent of mortalities as opposed to rejection in 22 per cent. Rejection and sepsis occurred in common in 11 per cent.[2] Infections in patients on immunosuppression can be very insidious and difficult to treat. We have found this particularly true in older patients who have received a cadaver kidney. Figure 3 illustrates a chest x-ray in a 50 year old male recipient of a cadaver kidney which was a D match. The patient did extremely well in his initial postoperative course. After discharge he was noted in a follow-up visit to have mild malaise and a slight cough. A chest x-ray demonstrated a small infiltrate in the left lung. This rapidly progressed to a severe bilateral lobar pneumonia (Fig. 4) and death 45 days after transplantation. Renal function remained excellent up to his death. The causative organisms appeared to be Herellea and Cytomegalovirus.

Using our schedule of immunosuppression, frequently there would be mild threatened rejection episodes as early as 10 days post transplantation. These would be manifest by an increase in the serum creatinine of over 0.2 mg. per 100 ml. in the absence of signs and studies indicative of other causes of renal dysfunction (infection, obstruction, vascular thrombosis, etc). Increase in the patient's weight, diminution of urine output, and diminution of urinary sodium and creatinine and an increase in urine protein usually occur. These are frequently accompanied by leukocytosis and, less commonly, fever. Tenderness over the transplanted kidney in our experience has been rare and unreliable as an indication of rejection. Other causes of renal dysfunction must be ruled out by physical examination and appropriate studies including intravenous pyelography, renal arteriography, isotope scanning, exploration, and biopsy.

Our practice is to treat a rejection episode by increasing the level of

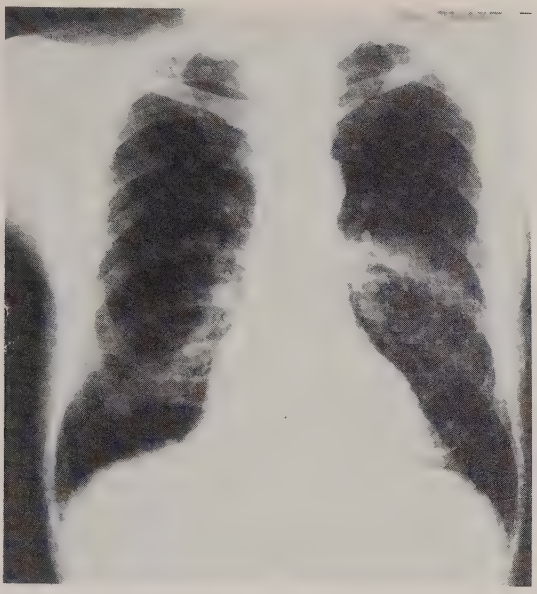

Figure 3. Chest x-ray of renal transplant recipient at follow-up examination, showing left pneumonic infiltrate.

Figure 4. Chest x-ray of renal transplant recipient just prior to death, showing bilateral lobar pneumonia.

Table 3. *Transplant Function and Patient Survival by Donor Group—Transplants Performed in 1969**

DONOR	1 YEAR		2 YEARS	
	Patient	Graft	Patient	Graft
Sibling (171)	83%	76%	76%	68%
Parent (163)	78%	70%	77%	66%
Cadaver (644)	67%	54%	61%	47%

*Adapted from the Ninth Report of the Human Renal Transplant Registry[2]

methylprednisolone to 500 mg. each day up to 10 days or 1 gm. every other day over the same period. These dosages are used as maximal figures. If a mild rejection episode responds easily to less than the maximal therapy, approximately half the course is given. Further, one or two courses of irradiation are given to the transplant.

It is important to treat rejection early and vigorously to prevent damage to the kidney. A poor prognostic sign is failure to restore a normal serum creatinine after treatment. Chronic rejection consists of repeated episodes of rejection with failure to restore renal function to previous levels. Thus a staircase course of increased serum creatinine usually can be plotted over time until complete failure of function occurs.

It has been shown consistently in transplant series that the period of greatest risk is in the first 3 months; this is followed by a period of lesser risk during the next 3 months. Beyond this point there are some additional losses up to one year. Few losses occur between 1 and 2 years except for the cadaver group which has a tendency to continue significant loss into the second year and beyond.

In summary, renal transplantation remains an exciting new area in surgery with a great deal of challenge. Much is still unknown in the prevention of rejection and in the best manner of handling both the routine care and the rejection episodes. It promises a new way of life to patients who otherwise would die of chronic renal failure or be dependent on a dialysis machine for their existence. It is exceedingly gratifying to see patients completely rehabilitated from a state of chronic invalidism to a normal life by renal transplantation.

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Hepatic Resection

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Prior to the last decade, there were few surgeons enthusiastic to perform hepatic lobectomy because of the poor survival statistics associated with this operation. However, with better anesthesia and blood replacement, improved preoperative and postoperative patient care, and increased knowledge of liver anatomy, hepatic lobectomy can now be undertaken with confidence that the patient will survive the operation and that the procedure might prove life-saving. The purpose of this paper is to describe the technique preferred by the author in performing an hepatic lobectomy and the reasoning behind various steps in the procedure.

PREOPERATIVE EVALUATION

The patient with a malignant hepatic neoplasm frequently presents with a mass in the upper area of the abdomen, usually the right upper quadrant. If the mass is consistent with a metastatic liver tumor, judgment must be exhibited as to how aggressive one should be in the preoperative work-up, since tumor which is distant from its primary location usually contraindicates further surgical intervention. An example of this would be the unwarranted performance of an inferior venacavogram in a patient with liver metastases from breast cancer. Conversely, a primary hepatic tumor demands an extremely thorough preoperative investigation, since an aggressive surgical approach to this situation frequently is justified.

All patients subjected to liver surgery require an hepatic arteriogram and liver scan in their preoperative work-up. Liver function studies must be carefully evaluated in these individuals, since marked variations from normal values might decide whether a major procedure upon the liver is indicated. An elevated bilirubin level, although distressing, is not as serious a preoperative finding as an elevated bromsulphalein (BSP) or a depressed serum albumin level, these latter two liver function studies being highly suggestive of possible functional inadequacy of the portion of the liver that would remain following a major hepatic resection.

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OPERATIVE PROCEDURE

An upper midline incision is made from the xyphoid process to just below the umbilicus. This allows for the rapid entry and wide exploration of the abdominal cavity, during which time the operating surgeon can determine the extent of intrahepatic tumor and the presence of any extrahepatic dissemination of malignant disease which would preclude further hepatic surgery. If a tumor is found confined to the left lobe of the liver, hepatic resection is usually possible without extending the incision into the chest. This is especially true if the tumor involves only the lateral segment of the left hepatic lobe. A right hepatic lobectomy always requires the exposure that can be gained only by having a wide thoracoabdominal incision.

In infants, it is possible to perform a right hepatic lobectomy without opening the chest because of the marked retractability of an infant's costal margin. Clatworthy,[2] however, stressed the importance of opening an infant's chest when doing an hepatic lobectomy because of the increased danger of an air embolism occurring when the negative pressure within the right pleural cavity is maintained in a closed chest.

When an hepatic tumor is found to be resectable, the midline incision is extended in a hockey-stick fashion into an appropriate interspace, the eighth or ninth usually being most satisfactory. Peritoneal attachments between the undersurface of the diaphragm to the liver are divided. A small piece (1 inch) of costal margin is removed when making the thoracoabdominal incision in order to facilitate closure of the chest at the end of the operation. The diaphragm is divided down to the inferior vena cava by cutting between an interrupted and parallel row of 2–0 silk sutures. This step is helpful in decreasing troublesome bleeding from the cut edges of the diaphragm.

The standard method for performing hepatic lobectomy, as previously described by Quattlebaum[6] and Lortat-Jacob,[4] is based upon three steps; (a) control of major vascular and biliary structures at the porta hepatis; (b) isolation and division of hepatic veins running between the liver and the inferior vena cava; (c) separation of hepatic parenchyma between the hepatic lobes.

The initial step in carrying out an hepatic lobectomy should be the isolation and division of the hepatic artery, portal vein, and hepatic duct leading to the liver lobe to be resected (Fig. 1). Occasionally, branching of these major vascular and biliary vessels does not occur at the porta hepatis, but deep within the hepatic parenchyma, thereby making control of these structures difficult and dangerous. Another technical problem that can limit one's ability to gain initial control at the porta hepatis is when a liver tumor is so large that it fills the upper and occasionally almost the entire right side of the abdominal cavity.

The second step one performs in carrying out a classic hepatic lobectomy is the isolation and division of hepatic veins running between the hepatic lobe to be resected and the inferior vena cava. Hepatic veins vary greatly in number, length, and diameter. When they are long and thin, their isolation, division, and ligation can be relatively simple. However, hepatic veins which are short and wide can be hazardous to control since

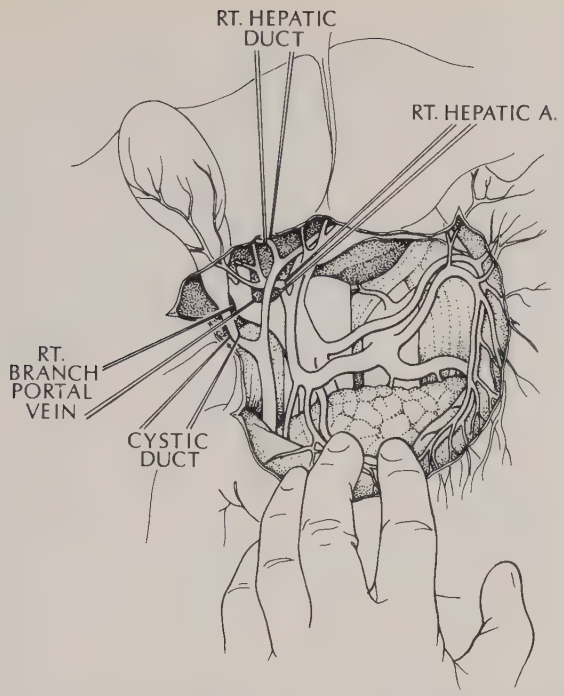

Figure 1. Major structures at porta hepatis.

their division at the inferior vena cava may require vascular suturing of this major venous trunk. The dissection of hepatic veins, therefore, demands excellent exposure. In attempting to gain this exposure, one must guard against a well meaning assistant inadvertently tearing an hepatic vein from the inferior vena cava by retracting the liver a little too vigorously.

If bleeding occurs at the junction of an hepatic vein and the inferior vena cava, an extremely serious problem is present which can quickly lead to death from exsanguination. This situation is most acute when bleeding from an hepatic vein occurs before the hepatic lobe has been removed, making the origin of this retrohepatic hemorrhage impossible to visualize. In this operative situation, the vena cava might have to be clamped, which can rapidly lead to cardiac arrest because of the marked reduction of venous flow to the right side of the heart. The problem of hemorrhage at the hepatic vein-vena cava junction is compounded by the possibility that an air embolism, which can be rapidly fatal, might occur.[1]

In order to obviate the dangers inherent in the surgical dissection of hepatic veins, this author has used during the past few years the finger fracture technique as devised by Lin.[3] This technique involves destruction of liver tissue by the fingertips with preservation of intact blood vessels and bile ducts which subsequently are individually ligated (Fig. 2).

The three basic steps of hepatic lobectomy, i.e., control of major vascular and biliary structures at the porta hepatis, division of hepatic veins, and separation of hepatic parenchyma, can, if necessary, be consol-

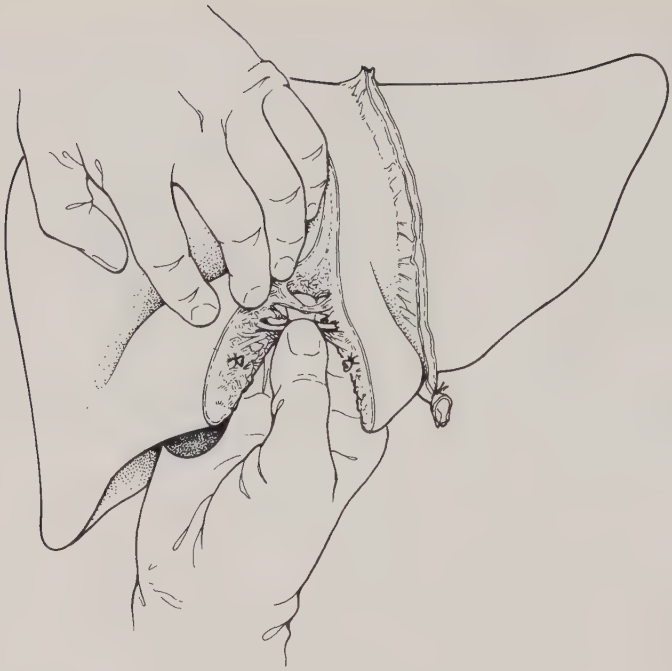

Figure 2. Drawing showing finger fracture technique with preservation of biliary and vascular structures.

idated into one basic maneuver by using the finger fracture technique. This may be indicated under difficult conditions when one is attempting to control the major vessels at the porta hepatis. The hepatic parenchyma can be entered directly with the fingers in the area either to the left or right of the imaginary line separating the individual hepatic lobes which runs from the gall bladder fossa inferiorly to the inferior vena cava superiorly. By using the fingers in this way, the major biliary and vascular structures to an individual lobe will be encountered approximately 1 inch below the surface of the liver, at which time the large vessels can be isolated and ligated. This finger fracture technique may be the only way one can gain control of the major vessels when a very large hepatic tumor overlies the porta hepatis, a condition commonly seen in the Far East.

A major advantage of hepatic finger fracturing is that it greatly lessens the dangers that can occur when operating upon hepatic veins. Securing these veins within the liver allows a sufficiently long stump of vein for ligation rather than having to resort to dividing the veins close to the inferior vena cava (Fig. 3). The intrahepatic isolation and ligation of hepatic veins also eliminates the need for retracting the liver, since this technique does not require exposure of the hepatic vein-vena caval junction.

By the time intrahepatic vessels have been isolated and ligated following finger fracturing, the hepatic parenchyma will have been divided between the two hepatic lobes and the involved lobe removed. Finger fracturing the liver is a great technical advance in liver surgery both in

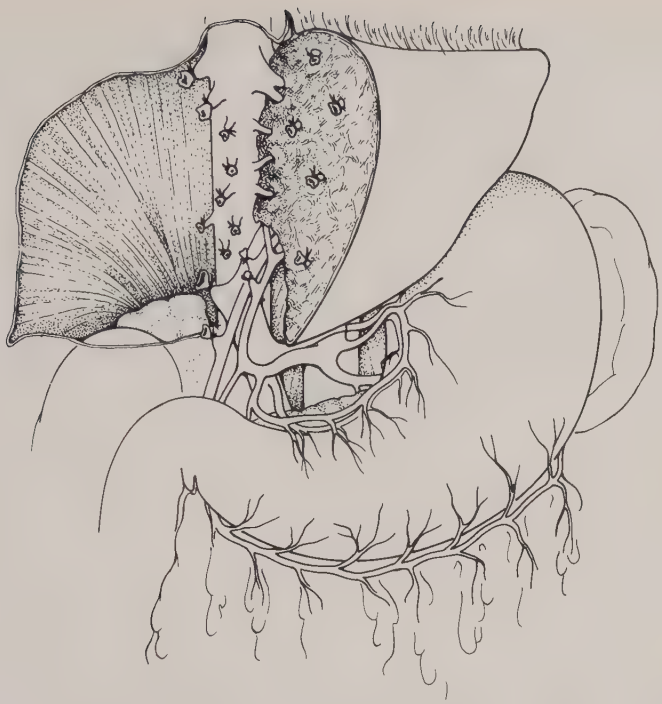

Figure 3. Picture illustrating the safety of ligating hepatic veins distant from their entrance into the vena cava.

terms of safety and in the shortened amount of time it takes to do an hepatic lobectomy. The author has personally seen Lin, the developer of this technique, do an extended right hepatic lobectomy in approximately 20 minutes, using only 2 pints of blood.

After completing a resection of a major portion of the liver, the question arises as to whether one should drain the common bile duct as advocated by Merendino.[5] This is done with the idea that the T-tube will decompress the biliary pressure, thereby decreasing bile drainage from the cut surface of the liver. This maneuver probably is a sensible step to take if the caliber of the common bile duct is of sufficient size to allow insertion of a T-tube without difficulty. This step is unwise if the lumen of the bile duct is small, as would be seen in a child.

It is important to cover the cut edge of the liver with some type of viable tissue after completing a hepatic lobectomy. The omentum is satisfactory for this purpose. After this structure has been surgically tailored to give it the length that is required, it is sutured to the cut edge of the liver with interrupted 3–0 chromic catgut sutures (Fig. 4).

Drainage of the operative site consists of bringing, through separate stab wounds, one Penrose drain from the cut edge of the liver and another from Morison's pouch. If a T-tube has been inserted into the common bile duct, this is also brought out through a separate stab wound. Stay sutures are used routinely in these cases.

In past years, it was a common practice during hepatic resection to

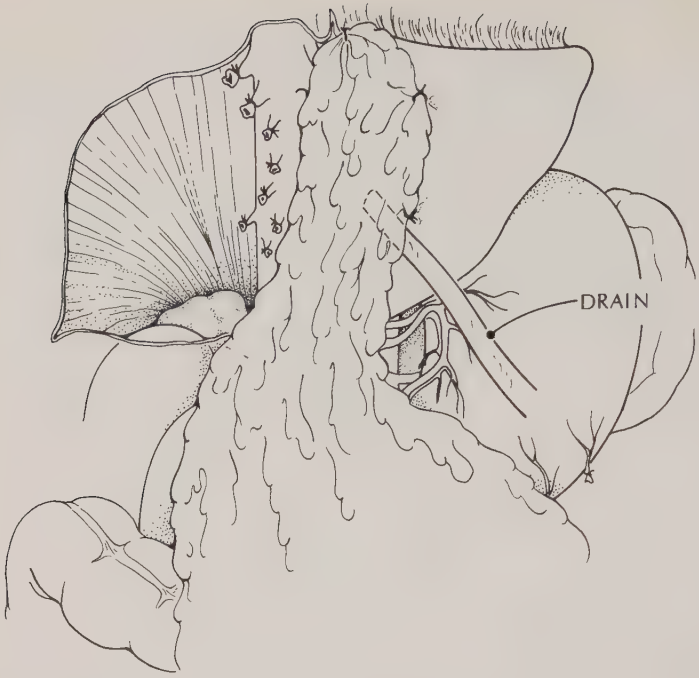

Figure 4. Omentum has been secured to divided edge of liver. Penrose drain is placed between omentum and liver.

control biliary and vascular leakage at the divided edge of the liver by using large mattress sutures which were deeply placed through the organ. These sutures caused liver destruction by their compressive effect which resulted in tissue necrosis and drainage which persisted for a long period. This clinical situation required the retention of abdominal drains for an extended period of time, during which the danger of introducing infection along the drain sites was always present. One must now seriously question whether there is any further need to use large mattress sutures in performing hepatic lobectomy, since the finger fracture technique allows for individual ligation of vascular and biliary vessels with a minimal amount of hepatic tissue being left behind to undergo necrosis. Drainage from the breakdown of devitalized hepatic tissue in these cases usually ceases after several days so that, in most instances, the abdominal drains can be removed within a week.

POSTOPERATIVE CARE

The postoperative requirements for patients undergoing an hepatic lobectomy closely resemble the needs demanded by any individual who has undergone an extremely large surgical procedure. Careful control of fluid and electrolyte balance must be maintained during the early postoperative period but, usually by the third or fourth day, the patient is on

an oral diet. Chest tubes are removed within the first 48 hours. What must be carefully observed during the early postoperative period is the albumin loss which is associated with this operation. It is a good idea to give at least one unit of albumin daily for 3 to 4 days following surgery and to administer additional amounts if the blood level of albumin remains low. Within 3 weeks the patient is usually well enough to be discharged from the hospital.

SUMMARY

The surgical maneuvers used by the author in carrying out hepatic lobectomy were described. It is felt that the finger fracture technique as devised by Lin has advanced the safety and speed of performing an hepatic resection.

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Management of a Pyogenic Abscess of the Liver

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Failure to drain a liver abscess usually results in 100 per cent mortality.[1, 5] Even when the abscess is surgically treated, complications following the operation are most frequently due to inappropriate surgical drainage.[2] The purpose of this paper is to describe the surgical treatment and postoperative care preferred by the authors in the management of a pyogenic abscess of the liver.

PREOPERATIVE EVALUATION

A patient harboring a liver abscess usually has clinical signs and symptoms which make the diagnosis of this condition readily apparent. Prominent clinical features are an elevation in the temperature, an enlarged liver which is frequently tender, and an elevated diaphragm which may be immobile. If the pleura overlying an hepatic abscess is involved with the inflammatory process, lower lobe pneumonia, with or without a pleural effusion, may be present.[3, 4]

Laboratory examination of the blood of a patient with an hepatic abscess usually shows an elevation in the white cell, bilirubin, and alkaline phosphatase levels with depression of the serum albumin fraction and the prothrombin time.[1]

In the preoperative evaluation of patients suspected of having a liver abscess, it is important to obtain an anteroposterior and a lateral liver scan in order to have some idea as to the location and extent of the intrahepatic lesion. Once the presence of an hepatic abscess has been confirmed, surgical drainage is required. Prior to operation, conditions such as anemia, a protracted clotting time, and a low serum protein level should be corrected when necessary.

Patients who are suspected of having a liver abscess are usually receiving some type of broad spectrum antibiotic. This antibiotic coverage should be administered up to and during the operation itself, and be

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continued into the postoperative period. Once material from the liver abscess has been cultured and sensitivity studies evaluated, the antibiotic which is specific for the infection can be administered.

SURGICAL MANAGEMENT

The authors have found an adequate right subcostal incision to be well suited for the exposure and drainage of a liver abscess. Many of the early papers dealing with pyogenic abscesses of the liver were reported in the preantibiotic era. Because of the added danger of infection during this period, an extraserous transthoracic approach to the liver was advocated as the best way to explore for a liver abscess, since it was felt that this approach would minimize the possibility of soiling the peritoneum with material from the abscess cavity. The authors do not use this approach but explore for a liver abscess through the peritoneum. It is felt that criticisms of this approach must be carefully weighed in relation to the excellent exposure one gains by this technique. The opportunity for the surgeon to palpate the entire liver greatly diminishes the possibility of inadequate surgical drainage and eliminates to a marked degree the possibility of a secondary liver abscess. The fear of peritoneal soiling with an intraperitoneal approach can be minimized by carefully walling off the liver with gauze pads and by using two suction catheters. The reason for having two suction catheters is that material within the abscess cavity can be removed at a faster rate than with a single suction catheter, thereby decreasing the danger of spillage, and it also minimizes the problem of having a single suction catheter become ineffective at the very moment when it is most needed.

When an hepatic abscess is located on the surface of the liver, an aspirating needle can be inserted directly into the cavity and all material removed. More difficult to locate and drain is an abscess which is located deep within the liver parenchyma which on occasion may have to be located blindly by use of an aspirating needle. Usually, however, the abscess can be found by carefully palpating for an area of hepatic softening which overlies an abscess formation. The presence of this abscess can then be confirmed with an aspirating needle.

When a liver abscess is close to the surface, the contents of the cavity should be removed and the wall of the abscess unroofed in order to prevent reaccumulation of material within the cavity. In an abscess that is deep within the liver, it is impossible to unroof the cavity and therefore an opening must be made directly into the abscess cavity. The electric cautery has been advocated as being a suitable instrument to use for this purpose.[1] The authors, however, prefer to create this tract by inserting a finger along the aspirating needle until the cavity is reached. It is felt that the finger is preferable to an electric cautery since it is less traumatic and would therefore tend to cause less damage to vascular and biliary ducts within the liver.

After an intrahepatic abscess has been located and a finger inserted into its cavity, careful digital exploration is carried out in order to break down any loculations, thereby creating a single hepatic cavity. Following

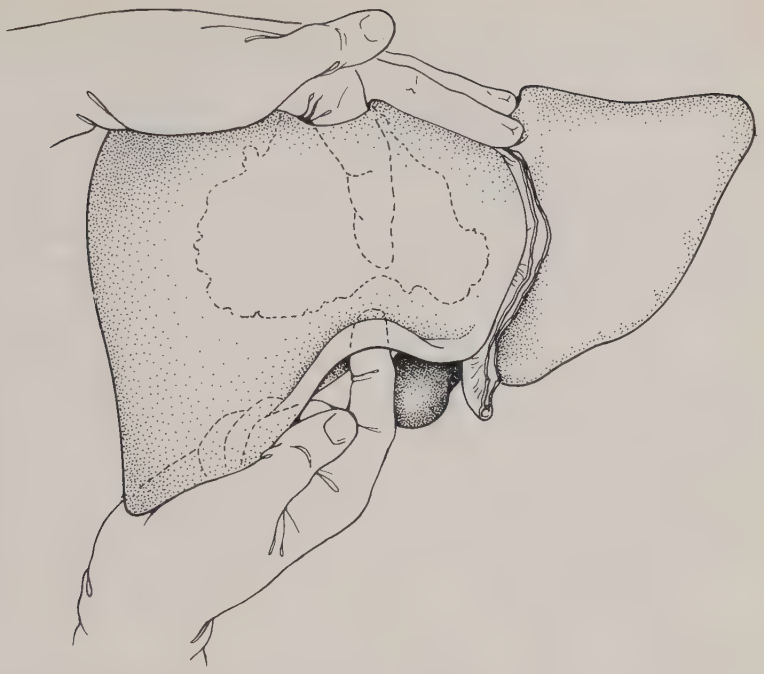

Figure 1. Upper finger has been placed in abscess cavity. Dependent drainage tract will be created through liver parenchyma separating forefingers.

this, the finger further explores the cavity in order to locate the most dependent position from which to make a definitive drainage tract (Fig. 1). This tract should be made with the realization that what is a dependent position on the operating table may not be so in a patient when in an erect or semi-Fowler position, the positions usually maintained by a patient during his postoperative course. Failure to drain the liver from a dependent position may result in the retention of material within the abscess and can explain why some abscesses require a secondary attempt at surgical incision and drainage.

PLACEMENT OF INTRAPERITONEAL DRAINS

The placement of a sufficient number of drains into and surrounding the liver is of extreme importance in the postoperative care of the patient. Two soft rubber catheters with multiple holes are placed into the abscess cavity through the drainage tract (Fig. 2). These catheters are used for irrigating purposes and the reason two are inserted is that during the subsequent course of treatment one may become clogged and completion of treatment then will depend upon irrigation through the auxillary catheter.

A sump drain is placed just at the entrance of the drainage tract into the liver. A large penrose drain is inserted immediately adjacent to the sump drain and additional large penrose drains are brought out through

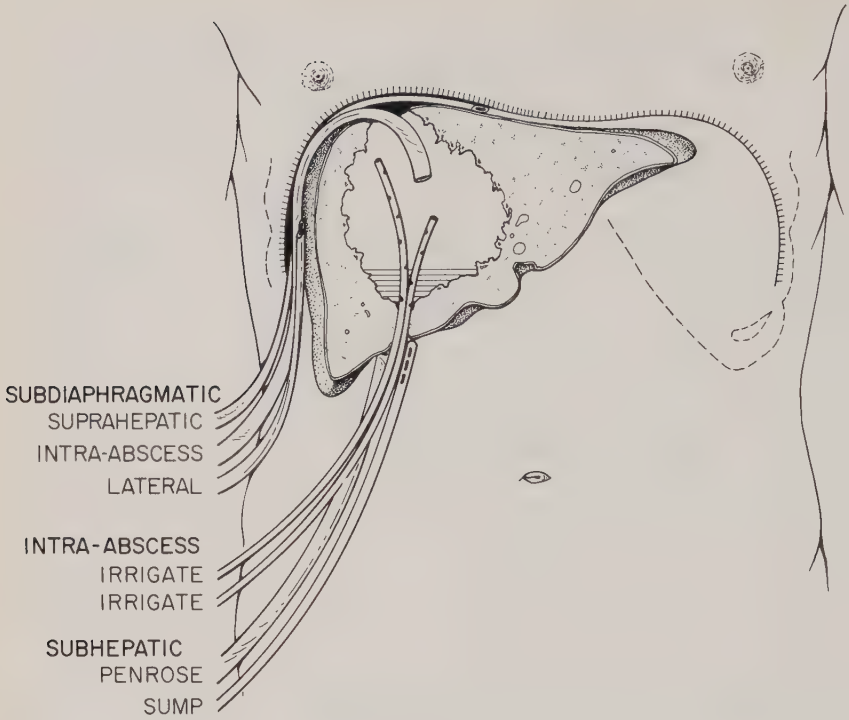

Figure 2. Drawing showing placement of catheters and drains in and around liver.

the top of the abscess cavity, from the suprahepatic area between the liver and the diaphragm, and from the lateral hepatic space.

IRRIGATION OF ABSCESS CAVITY

The most important part in the postoperative care of a patient with an intrahepatic abscess is the careful irrigation and aspiration of material from the abscess cavity. This irrigation is done preferably by the surgeon who performed the surgery and who has intimate knowledge of where the drains and catheters have been placed both in the liver and in the perihepatic areas.

The basic treatment of an hepatic abscess is to irrigate with large volumes of saline which are quickly retrieved by way of the sump drain placed at the entrance of the drainage tract. Irrigation is usually begun approximately 12 to 24 hours after surgery. During the first 2 or 3 postoperative days, the sump drain is kept on continuous suction, but after this period of time it is usually necessary to have the sump drain placed on suction only during the time that the abscess cavity is being irrigated. It is important that the irrigation be done gently so that there is a minimum of inadvertent spillage of material out of the abscess cavity into the perihepatic spaces. In spite of careful attention to this possibility, some spillage may occur and it is for this reason that penrose drains are placed

in the superior, lateral and sub-hepatic spaces. It is these penrose drains which serve as an avenue for irrigating material not immediately aspirated through the sump drain.

Early in the postoperative course, the abscess cavity is irrigated three times a day using approximately a liter of saline with each irrigation. It will be noted that early in the treatment of the abscess, the material which is aspirated through the sump drain immediately after the initiation of saline irrigation will be purulent. It will be found that a large volume of saline must be irrigated through the catheter before the material exiting through the sump drain becomes clear. After approximately a week of treatment, the material coming from the abscess cavity will clear more rapidly with the saline irrigations until eventually the saline which is initially placed into the abscess cavity will be removed rapidly by the sump drain and will have a clear appearance. This indicates that the infectious process is being controlled. As soon as saline begins to appear in the sump drain almost immediately after irrigation into the abscess cavity, one can be certain that there has been marked contraction of the abscess cavity and a tapering off of further irrigations can be started. At this time, the penrose drains are gradually shortened until all drains and catheters are removed from the abdominal cavity.

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Evaluation of the Patient with a Breast Tumor

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This past decade has witnessed a remarkable increase in public awareness of the specter of breast cancer, and many women's magazines have devoted space to discussions of the present controversy among physicians as to the optimum treatment for mammary carcinoma. As the medical sophistication of the average woman increases, physicians justifiably may be questioned more rigorously and vigorously by their patients before they accept any recommended form of therapy for breast complaints. Mammography and other diagnostic tools have been similarly popularized, and, just as the patient with a traumatic injury has come to expect an x-ray to be taken of the injured part, the patient with a breast complaint has all but come to expect that her physician will use any or all of these ancillary aids as part of her evaluation.

In the light of these advances in diagnostic techniques as well as the continued widespread controversy regarding treatment, it is not only pertinent but desirable that a system or outline be suggested to aid the practitioner or surgeon who does not specialize in breast diseases, in his approach to the patient with a breast complaint or with the finding of a mass within the breast.

To place the significance of the subject in its proper perspective, about 25 per cent of women will, during their lifetime, seek medical attention because of a breast complaint.[2] One of 19 women will develop carcinoma of the breast, and although this is a remarkably high incidence, it represents only a small proportion of all women with symptoms of breast disease. A majority of patients will be found to have engorgement of their breasts, manifested by pain or nodularity, or they will have benign lesions of physiologic origin, such as cystic disease. A smaller number will have benign neoplasms such as fibroadenoma or intraductal papilloma. Therefore, it is essential in formulating a "plan of attack" to remember that most breast lesions are not malignant, but that their removal may be warranted to insure that malignancy is not present. Because the clinical diagnosis of these lesions is subject to error, up to 25 per cent in the best of hands, only microscopic proof of benignancy is acceptable. The latter

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statement does not imply unequivocally, however, that the mere presence of a breast mass is reason enough for its excision.

Most women who seek medical attention believe that they have discovered new disease within their breasts. Other women come to the physician because a friend or relative has been recently discovered to have breast cancer, and they are frightened of the same fate. The preliminary discussion with the patient, as with any other complaint, should include a careful history, specifically inquiring about symptoms, past history of breast disease, reproductive history, and family history. The initial symptoms should be related to the time and method of discovery. Most women with breast complaints are convinced that they have a tumor – they or their physician has noted an actual mass, or perhaps a knot or thickening in their breast. Inquiry should determine if there has been any change noted between the discovery of a mass and the present examination, and if such changes have been noted in relation to the menstrual cycle. If the lesion under consideration is noted only premenstrually or during the menstrual flow, increased physiologic nodularity is suggested rather than any specific lesion or disease.

Pain and tenderness, although of considerable concern to the patient, are poorly correlated with the pathophysiology of breast disease. Pain is a frequent complaint, usually more so in one breast than the other, and is often temporarily related to the menstrual cycle. It is most noticeable after ovulation and increases until the end of the cycle, with decreasing discomfort beginning with the onset of menstrual flow. Pain is characteristically absent with carcinoma, and it is not a prominent symptom with cystic disease, unless a cyst has enlarged rapidly.

Discharge from the nipple is an infrequent but disturbing symptom. Women have been so sensitized by articles in the lay press about the "warning signals" of cancer that discharge from the breast is a complaint accompanied by marked anxiety. It is important to emphasize to these women that such discharge may be innocuous, especially if it is not spontaneous, but elicited only by squeezing or manipulating the nipple or breast. The ubiquitous use of oral contraceptives may result in spontaneous discharge of a serous but not serious nature. The most common lesion producing nipple discharge, serous or bloody, in the nonlactating female is an intraductal papilloma.[2] Less frequent causes are mammary duct ectasia, cystic disease, and carcinoma. Because, however, discharge may be associated with the presence of carcinoma, it is certainly a symptom requiring investigation. Only in the presence of pregnancy or lactation, or coincidental with the administration of oral contraceptive drugs, may the investigation of spontaneous nipple discharge be delayed.

Because many women seen for the first time have a prior history of breast complaints for which they have previously received medical care, it goes without saying that data from previous biopsies or operations should be sought. Whenever possible, the histologic slides should be reexamined or the tissue blocks recut to be certain of any prior diagnoses.

The reproductive history is similarly important because of its possible relationship to breast disease. The catamenia should be outlined, including date of menarche and the regularity as well as frequency and duration of menses, and all pregnancies should be noted. Dates of meno-

pause or gynecologic operations should be recorded. The intensity and duration of menopausal symptoms should be recorded as well as any history of hormonal therapy to postpone such symptoms. Inquiry should be made about the use of beauty creams containing estrogens. The nursing history is also recorded, i.e., if the patient herself was nursed, and in turn, if she nursed her own children, and in either case, the duration of nursing.

Because breast cancer does occur more frequently among relatives of patients who have had breast cancer, it is essential to inquire if any members of the patient's family have ever had mammary carcinoma, and if so, the age at which it was noted. When there is a familial history, breast cancer tends to occur about 10 years earlier in each succeeding generation.[5]

PHYSICAL EXAMINATION

Diagnosis of breast disease and the differentiation of the various lesions which may affect the breast depend upon the care exercised by the examining physician in performing the physical examination. A cursory examination, passing the hands superficially over the breasts with the patient in an upright, erect position, prior to the auscultation of heart and lungs, will fail to detect many breast lesions. Proper examination of the breasts requires a systematic and uniform routine, including changes in the patient's position, and careful palpation over the entire breast and chest wall, as well as the node-bearing areas of the axilla and supraclavicular area. When this preliminary examination indicates the possibility of a lesion being present, still other maneuvers and more time are required.

The examination begins with the patient in the erect sitting position facing the examiner. Despite concern for the patient's modesty, it is important that she be disrobed to the waist. It is most convenient to begin the examination with palpation of axillary and supraclavicular areas, even before palpation of the breasts themselves. Findings in the supraclavicular areas are noted if there are nodes palpable, and if so, whether the nodes are "clinically involved by tumor." Involvement of the nodes in the supraclavicular space by breast cancer implies advanced regional node metastases and probable incurability.

Examination of the axilla requires relaxation of the pectoral major muscle to allow the hand of the examiner to be inserted deep to that muscle (Fig. 1). The degree of pectoral relaxation necessary is achieved easily by supporting the patient's arm on the examiner's. The physician stands at the patient's side, cradling her arm in a flexed position. The axilla is examined gently with the tips of the fingers of the contralateral hand; i.e., the examiner palpates the patient's right axilla with his left hand. The ability to identify small lymph nodes is directly related to the gentleness of the examination. Obesity increases the difficulty of the examination. Number, consistency, and mobility of the axillary nodes should be recorded, as well as the symmetry of the two axillae. It is advisable to estimate the size, i.e., transverse diameter, of the largest axillary

Figure 1. Palpation of the axilla; supporting the patient's arm and gently palpating the axilla with the fingers of the contralateral hand. (Modified after Haagenson, C. D.: Diseases of the Breast. Philadelphia, W. B. Saunders Co., 1971.)

node or group of matted nodes. Many women may have palpable axillary nodes, especially if they do their own housework and sustain occasional small abrasions or cuts on their hands or fingers. Women whose nails are manicured may also exhibit soft palpable axillary nodes. After palpating both axillae and recording the objective findings, the examiner should also indicate if the axillary nodes are "clinically involved by tumor." This judgment should be entered on the patient's record.

Following examination of the supraclavicular areas and the axillae, the breasts are inspected with the patient sitting erect with her hands at her sides, and then with her arms elevated above her head (Fig. 2). Raising the arms may elicit retraction signs not otherwise apparent. The breast contour is noted, from the edge of the latissimus dorsi muscle laterally to the midline. An indentation or asymmetry of contour may disclose the site of a lesion. Finding one breast larger than the other is normal and expected. At this same time, the skin over the breast is inspected for redness, edema, ulceration, prominence of subcutaneous veins, or satellite nodules.

The nipples and areolae are also inspected with the patient in the erect position, looking for changes such as retraction, inversion, or devia-

Figure 2. Asymmetry of contour and retraction signs are demonstrated in the medial portion of the left breast by elevation of the arms above the head.

tion of the nipple axis. Examination of the nipple epithelium is performed later with the patient recumbent.

Palpation of the breast is accomplished with the patient recumbent and the breast flattened upon the chest wall. Depending upon the size of the breast, the patient may need to be turned with the side to be examined thrown forward, or with a small pillow inserted under the shoulder and trunk of the side being examined. This maneuver throws the breast medially and flattens it against the chest wall, rather than permitting it to fall to the side of the chest wall. It is essential to emphasize gentleness of palpation to elicit evidence of disease. Heavy-handedness is less likely to yield results and is also uncomfortable for the patient. The breast is not kneaded, but is palpated with the flat of the fingers of one hand in a uniform manner. The medial half of the breast is optimally palpated with the patient's arm abducted and the hand cupped on top of her head, tensing the pectoral muscle and providing a flat surface against which the breast rests (Fig. 3). The examiner's fingers then go back and forth along the medial half of the breast, from sternum to nipple line, cephalad at the clavicle to the inframammary fold. The hand is then brought partway down to the side, with the upper arm still abducted at about 90°. The lateral half of the breast is then palpated from the nipple line to the edge of the latissimus dorsi muscle laterally from the inframammary fold to the clavicle (Fig. 4).

In patients with large, pendulous breasts, the portions of breast caudad to the nipple, i.e., the lower quadrants, should also be palpated with the patient sitting erect. The thickness of breast when the patient is

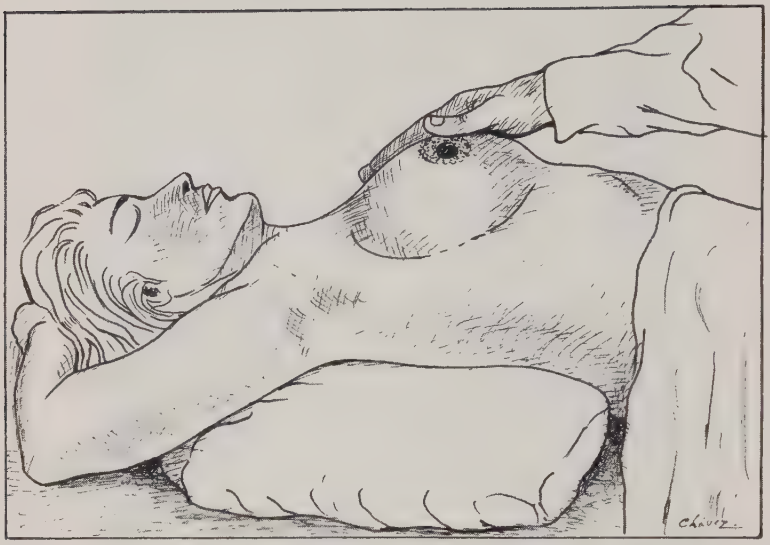

Figure 3. Correct method for palpation of the medial (inner) half of the breast; arm raised above the head, small pillow under the ipsilateral shoulder and thorax. (Modified after Haagensen, C. D.: Diseases of the Breast. Philadelphia, W. B. Saunders Co., 1971.)

Figure 4. Palpation of the lateral half of the breast; arm at side, small pillow under ipsilateral shoulder and thorax. (Modified after Haagensen, C. D.: Diseases of the Breast. Philadelphia, W. B. Saunders Co., 1971.)

in the supine position may render a small mass impalpable, whereas such a lesion may be felt between the fingers with the patient erect.

Throughout the course of the examination, the one question which the physician must continually bear in mind and answer is whether there is a dominant mass present within the breast. When a single, sharply defined tumor is present in an otherwise unremarkable breast, the answer is easy, but unfortunately, the more frequent dilemma is whether the increased nodularity felt is within the limits of normal or it represents a dominant mass caused by inflammation or neoplasm.

Because of its lobular structure, the breast may be expected to have a nodular character upon palpation. This may be characterized as finely or coarsely nodular, depending upon the state of engorgement or upon the menstrual cycle. The degree of nodularity may be such that it is difficult to delineate between normal breast tissue and a dominant mass. Although descriptions likening clinical findings to fruits and vegetables are generally to be deplored, an analogy which immediately defines the problem in terms understood even by the neophyte is that of "feeling for a pea in a bowl of tapioca pudding." Most breast disease takes the form of a single dominant tumor; increased physiologic nodularity may take the form of scattered nodularity in one or both breasts. Cystic disease, which may produce multiple dominant tumors, is the exception.

Not infrequently, careful physical examination fails to disclose a dominant mass despite the patient's history of a tumor being noted by her or another physician. It is imperative that the examiner ask the patient to demonstrate any tumor she or her physician has found. It should not be considered humiliating for the examiner to have the patient demonstrate a definite lesion despite its being overlooked by the examiner. More often, the patient's impression of a tumor proves to be an area of increased nodularity or even a prominent costochondral junction. By discussing negative findings with the patient, she is reassured that the examiner has not overlooked a lesion which had seemed obvious to her, but rather that her observations, although valid, are not clinically significant. Occasionally, the examiner may find a second lesion, having entirely overlooked the lesion for which the patient sought attention.

It is often impossible to be certain of the presence or nature of a suspected mass in the breast if the patient is in the premenstrual phase of her cycle. If there is any question of the presence of a mass, it is prudent to ask the patient to return for a second examination between the end of her menstrual cycle and the time of ovulation. An alert office secretary may avoid the need for such return visits by asking premenopausal patients for the dates of their menses, and scheduling appointments for examination only during the appropriate phase of their cycles. Change in the size of a lesion in relation to the menstrual cycle is strongly in favor of the lesion being due to cystic disease.

Once a dominant mass has been identified, it is then necessary to define it further in terms of its physical qualities, namely, size, shape, degree of circumscription, consistency, and mobility.

The size of the tumor should be noted by measuring its largest diameter. One measurement may suffice if the mass is spherical in shape, but

three-dimensional measurements may be necessary if the lesion is irregular in outline.

The shape of the tumor should be noted. Commonly used descriptions are spherical, discoid, elongated, nodular, and irregular.

Perhaps the most important physical characteristic to be noted to differentiate benign from malignant lesions is the degree of circumscription or delimitation, the ease with which the edges of the mass may be felt and defined. Cysts and benign tumors are usually well circumscribed, and most cancers tend to be poorly circumscribed, infiltrating into the contiguous tissue. Exceptions to these general rules are frequent, and certain types of cancers, especially the circumscribed (medullary) or papillary varieties, may be quite well circumscribed in outline.[5]

Consistency is a less valid guide to the nature of a breast lesion. Generally speaking, carcinomas are extremely firm or hard, and cysts are rubbery or elastic. Small masses, however, are difficult to characterize in consistency.

Mobility of a lesion within the contiguous breast tissue is a relatively reliable guide to its nature. Benign lesions usually slip about readily beneath the examining finger, whereas cancer is usually firmly fixed within the breast, without much mobility. Adenosis and fat necrosis, however, represent benign lesions which mimic cancer in this regard, and medullary (circumscribed) cancers are known for their mobility.[5]

In addition to palpation, an important next step in the evaluation of the patient is the search for retraction signs. These may range from a small puckering in the skin over the breast to marked shrinkage and deformity of the entire breast. Retraction is produced by fibrosis within or contiguous to a carcinoma exerting abnormal traction upon Cooper's ligaments, pulling the skin inward and ultimately fixing the breast to the underlying pectoral fascia and muscle. Contraction of the pectoral muscles may elicit retraction signs by distorting the breast contour (Fig. 5). If larger mammary ducts are involved centrally, the nipple axis may be affected and flattened, retracted, or inverted.

Retraction signs may be ovious, or they may be so subtle as to defy detection. Elevating the hands above the head may reveal asymmetry of the breasts or retraction of the skin. Molding the breast, or lifting it gently upward while gently cradling it within the hand, may elicit dimpling in the upper half of the breast although none is seen in the dependent breast (Fig. 6). The same molding maneuver with the patient recumbent may locate retraction in the lower quadrants of the breast. Pectoral contraction with the patient seated with arms akimbo, resting hands on hips, then pushing hands against the hips, may reveal a sharp upward rise in a diseased breast.

Forward bending may also demonstrate retraction. The patient stands and bends forward from the hips, extending the hands toward the examiner who supports them. Normal breasts fall free from the chest wall and appear symmetric. If retraction is present in one of them, it may fix the breast to the chest wall in such a way as to produce asymmetry that can be detected by observation from the side or front of the patient.

As carcinoma extends locally within the breast, the tumor and then the breast itself become fixed to the underlying pectoral muscle and fas-

Figure 5. Retraction signs demonstrated over a tumor of the right breast, elicited by pectoral contraction with hands on hips.

Figure 6. Demonstration of dimpling (arrow) by gentle molding of the breast. (Modified after Haagensen, C. D.: Diseases of the Breast. Philadelphia, W. B. Saunders Co., 1971.)

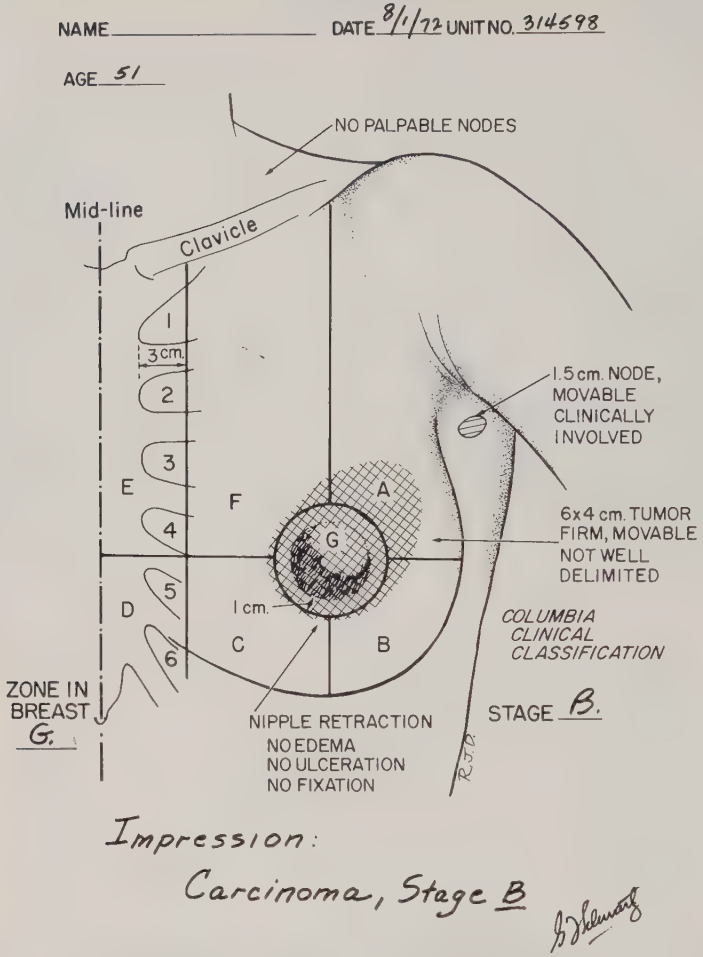

Figure 7. A printed diagram of the breast with clinical findings drawn in. (Modified after Haagensen, C. D.: Diseases of the Breast. Philadelphia, W. B. Saunders Co., 1971, with permission.)

cia, then finally to the chest wall. Minor degrees of fixation should be differentiated from solid fixation of the tumor to the chest wall.

The notation of the physical findings is most important. In the hospital, the work-up is usually performed by a clinical clerk or junior house officer. This kind of record often fails to allow later reviewers to appreciate the findings noted by the attending surgeon. Although a photograph may record the physician's observations quite accurately, it is unable to reflect the palpatory findings without further notation. A simple sketch of the breast and chest wall, including the axillae and supraclavicular areas, is indispensable. Printed diagrams of the breast are available for physicians with less artistic talents. The examiner may chart his exact findings with the patient recumbent and mark them upon the diagram for later review (Fig. 7).

OTHER DIAGNOSTIC TECHNIQUES

Mammography

Although soft tissue roentgen studies of the breast were initially reported as long ago as 1930, the late 1950's witnessed a resurgence in their utilization as aids in the diagnosis of breast masses. Advocates of mammography have been extremely vocal and persuasive in their enthusiasm for the technique as a means of discovering mammary carcinoma in its preclinical stages with a high degree of accuracy. Unfortunately, mammography has not been used long enough and under well controlled situations to determine if it is a feasible screening procedure, or if it results in improved overall survival by the earlier detection of breast cancers. There is no question that, under ideal conditions, mammography will detect tumors of the breast too small to be palpated, but there is no proof yet that detection of cancers at this stage has led to increased survival of these patients when compared to patients with small palpable lesions. The cost of mammography in both time and money is considerable; mammography may take 2 hours to perform and costs approximately $60 to $75.00. An adequate clinical examination takes one fourth as long and costs one fourth as much as mammography!

Even the strongest advocates of mammography deprecate its use in young women because of the difficulty of interpretation as well as the radiation exposure involved. Presently, mammography should be reserved for those patients who present problems in the interpretation of clinical findings. These patients are to be differentiated from women with "lumpy breasts" or breasts that are "difficult to examine." Many young women fall into these latter categories, and serial mammography would be a disservice to them. The clinically puzzling patient is, for example, the patient who demonstrates distortion of the breast contour, or deformity of the nipple or areola. Mammography is also helpful in the detection of masses in the large fatty breasts of older women, and the initial clinical examination of the breast should be supplemented by mammography in these patients, especially when they fall into the high risk category (vide infra).

Xerography

The same comments pertain as for mammography. Advantages of xerography are the decreased radiation exposure and the alleged increased clarity and delineation of the image, making the detection of lesions easier and more likely.

Thermography

In 1958, Lawson demonstrated that mammary carcinomas may emit more heat than the contiguous normal tissue and began to investigate the use of an infrared scanning device to detect these temperature differences. Thermography has been touted as a significant advance in the early detection of mammary carcinomas. A study is underway presently to determine the value of thermography as compared to mammography and/or clinical examination in the detection of breast disease in the asymptomatic patient. Available data indicate that a negative ther-

mogram may be significant in predicting freedom from breast carcinoma for a period of at least 3 years following the negative examination.[6]

It should be stressed repeatedly that these techniques of mammography, xerography, and thermography, although initially developed and advocated for use in screening asymptomatic patients, are occasionally valuable in the work-up of a patient with a palpable mass. They are indicated not necessarily as an adjunct to the diagnosis of the clinically palpable lesion, but as a technique of examining the contralateral breast. Reports of coincidental bilateral mammary carcinoma are increasing, and the increased incidence of contralateral carcinoma in patients who have already had carcinoma of one breast is well known.

THE TENTATIVE DIAGNOSIS

After the clinical history and physical examination have been completed, the examiner must decide whether he is dealing with a physiologic condition such as increased nodularity of the breast, or if there is a reasonable suspicion of the existence of actual breast disease. For the former, nothing need be done except to reassure the patient. In the event of the latter, a decision must be made as to further management to identify and confirm the nature of the lesion. In the course of reviewing the history and physical findings to make this decision, the physician must mentally check off the presence or absence of several indications of disease which always justify further investigation. Specifically, these findings are (1) the presence of a dominant mass, (2) increase in the size or firmness of one breast, (3) signs of retraction, (4) erythema or edema of the breast, (5) spontaneous nipple discharge, (6) changes in the epithelium of nipple or areola, and (7) mammographic or thermographic evidence of disease.

PROVING THE DIAGNOSIS

A tentative diagnosis is not sufficient to satisfy either physician or patient! Proof is necessary, since the indicated therapy is so different for different diseases. Benign lesions usually require nothing more than limited local excision, whereas carcinoma may require a formidable, mutilating operation that should never be performed needlessly. The only evidence considered reliable is pathologic, and the manner in which one proceeds toward this pathologic diagnosis is influenced by the tentative diagnosis. Thus, there is no substitute for careful examination and disciplined experience in arriving at the tentative diagnosis.

Generally speaking, almost all lesions of the breast in the adult female must be treated by biopsy and microscopic study of the lesion to prove the diagnosis. If the patient is young, and the tumor has the clinical appearance of a fibroadenoma, she and her family may be reassured. Removal of the lesion may be postponed until a convenient time, e.g., school recess or a planned vacation. The likelihood of missing a carcinoma within this age group is small. Should the lesion prove to be a cyst

rather than a fibroadenoma, no harm will have been done. If the patient is within the usual child-bearing age, and if the lesion has the clinical characteristics of a cyst, it is reasonable to perform aspiration, using local anesthesia and a fine gauge needle. If the typical fluid is encountered and the lesion disappears completely, it is safe to assume that the lesion is cystic disease, and no further surgery is necessary. If, however, the lesion proves to be solid rather than cystic, or if aspiration does not result in its complete disappearance, it is essential that biopsy be performed.

Despite occasional enthusiasm for aspiration biopsy, trocar or trephine biopsy, intraductal biopsy, or histologic studies of nipple secretions obtained by expression, the method of choice to prove the diagnosis of a breast lesion remains open surgical biopsy under general anesthesia, with immediate examination of the specimen by the pathologist. Biopsy in the physician's office under local anesthesia is avoided because of the anxiety it produces while the patient awaits the pathologist's decision, and because of the occasional difficulty in locating the lesion after the infiltration of the area with anesthetic agent. The excision of a small wedge of nipple or areola as an office procedure if Paget's disease is suspected is an exception to this general rule.

When biopsy is performed in the hospital under general anesthesia, the patient is prepared beforehand for the possibility of radical mastectomy, should the diagnosis prove to be carcinoma and the lesion be considered potentially curable by this procedure (Columbia Classification A or B;[3] International Classification, Stage I or II.) Despite the controversy regarding the treatment of choice for early mammary carcinoma, there appears to be no evidence yet extant which unequivocally demonstrates that therapy other than classical Halstedian radical mastectomy has achieved long-term survival rates (10 years or more) as high as those achieved by radical mastectomy.[4] These alternative therapeutic modalities have included simple mastectomy with or without postoperative radiation therapy, tumor excision alone, with or without radiation therapy, conservative or modified radical mastectomy, extended radical mastectomy with chest wall and internal mammary dissection, and radiation therapy alone. Discussion of this controversy is beyond the scope of this monograph. Needle biopsy, using a Vim-Silverman or Menghini needle, is reserved for special circumstances, e.g., proving the diagnosis in a patient considered constitutionally too feeble for radical mastectomy, or if the lesion is far advanced, and histologic proof is necessary before radiation therapy is begun.

TECHNIQUE OF BIOPSY

The general practice throughout the country is excision of the entire tumor for biopsy, the usual argument favoring this practice claiming that likelihood of metastasis is less if the line of excision is around rather than through the tumor. Because carcinoma frequently infiltrates far beyond the grossly visible edge of disease, it would appear to be fallacious to assume that any local excision would get entirely beyond the tumor. Since one cannot be certain of avoiding carcinoma whether incising it and

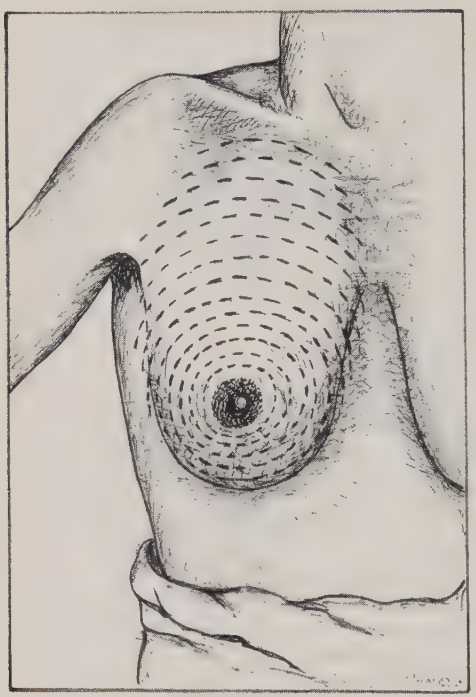

Figure 8. Langer's lines in the skin over the breast. (Modified after Haagensen, C. D.: Diseases of the Breast. Philadelphia, W. B. Saunders Co., 1971.)

removing only enough tissue to make the diagnosis, or excising the tumor in toto, it seems reasonable to disturb the lesion as little as possible. Thus, this author has adopted incisional biopsy and frozen section as the method of choice in proving the nature of breast tumors. The patient is physiologically and psychologically prepared for radical mastectomy, should it be required. If the tumor is presumed to be a carcinoma, a small incision is made through the skin overlying the tumor in the skin lines (Langer's lines) parallel to the areolar margin (Fig. 8). When the lesion lies peripherally in the breast, it is preferable to place the biopsy incision at the edge of the tumor nearest the areola, i.e., centrally within the breast, still parallel to the areolar margin, so that, if radical mastectomy is necessary, the mastectomy incision will be as far as possible from the site of the biopsy, without the need for placing the mastectomy incision unnecessarily beyond the midline medially or past the edge of the latissimus dorsi muscle laterally.

If the tumor is solid, a small wedge, 3 x 5 mm., is excised for histologic examination. Occasionally the pathologist may need a second small piece of tumor if the diagnosis is difficult. The entire lesion is not excised unless it is a small one (and the differentiation between incisional biopsy and excisional biopsy is an exercise in semantics). If the lesion does prove to be malignant, the biopsy is closed tightly with a continuous suture, leaving a gauze sponge in place within the wound. The wound is then sealed with a large piece of rubber dam cemented in place with dermatome glue. The operating team changes gowns and gloves,

and care is taken to insure that the surgical field is free from possible contamination from the biopsy before beginning the radical mastectomy. Radical mastectomy is performed according to the technique described by Haagensen, sacrificing skin widely and cutting thin skin flaps.[1, 2]

Should the lesion prove to be benign, it is excised in its entirety, including only a narrow rim of contiguous parenchyma. As little normal breast tissue as possible is removed so that deformity of the breast does not result.

If the clinical characteristics of a breast tumor suggest that it is benign, although the patient may be prepared for radical mastectomy, placement of the skin incision is varied. A circumareolar incision is used, placed exactly at the areolar margin. Such incisions placed in the skin lines and carefully approximated with fine suture material are almost invisible after they heal (Figs. 9 and 10). Using such a circumareolar incision, it is possible to expose lesions situated at some distance from the edge of the areola by elevating a subcutaneous flap just above the superficial fascia of the breast. The wound is closed in two layers, the deep layer of 00000 non-absorbable (silk or synthetic) sutures placed in the subcuticular fascia or areolar muscle, and a cutaneous layer of 00000 nylon interrupted sutures. The layer of subcutaneous sutures keeps the scar from widening after the skin sutures have been removed. Whether the "dead space" in the depths of the wound is closed after the excision of a benign breast lesion is a matter of personal preference. This author favors meticulous hemostasis and no attempt at apposition of the tissues in the depths of the wound. Despite careful placement, sutures so employed may cause some deformity of the breast when the patient is erect and the breast is dependent.

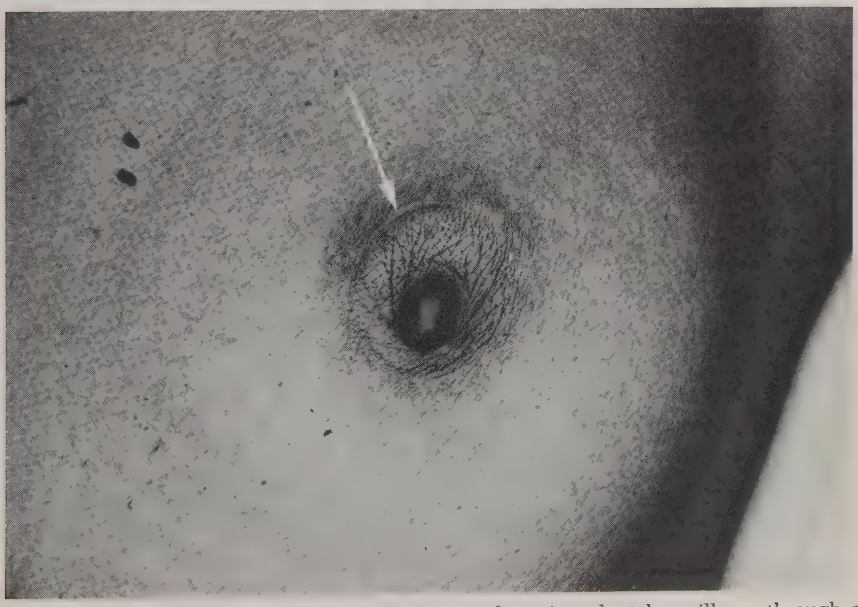

Figure 9. Invisible scar following excision of an intraductal papilloma through a circumareolar incision.

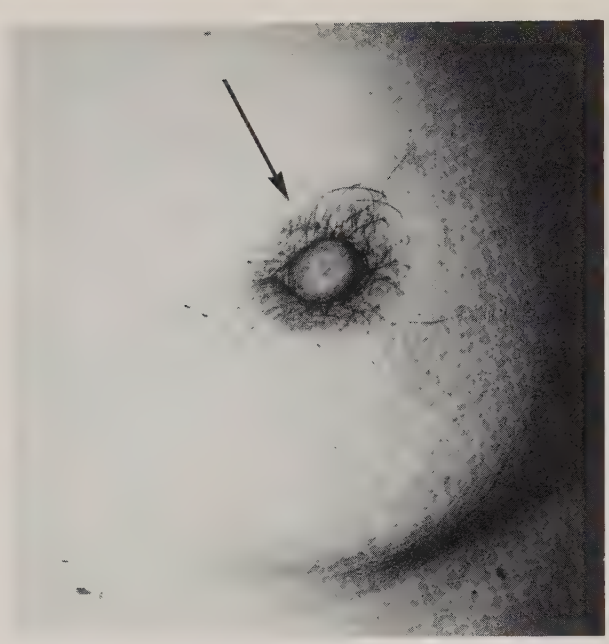

Figure 10. Invisible scar following excision of a fibroadenoma using a circumareolar incision.

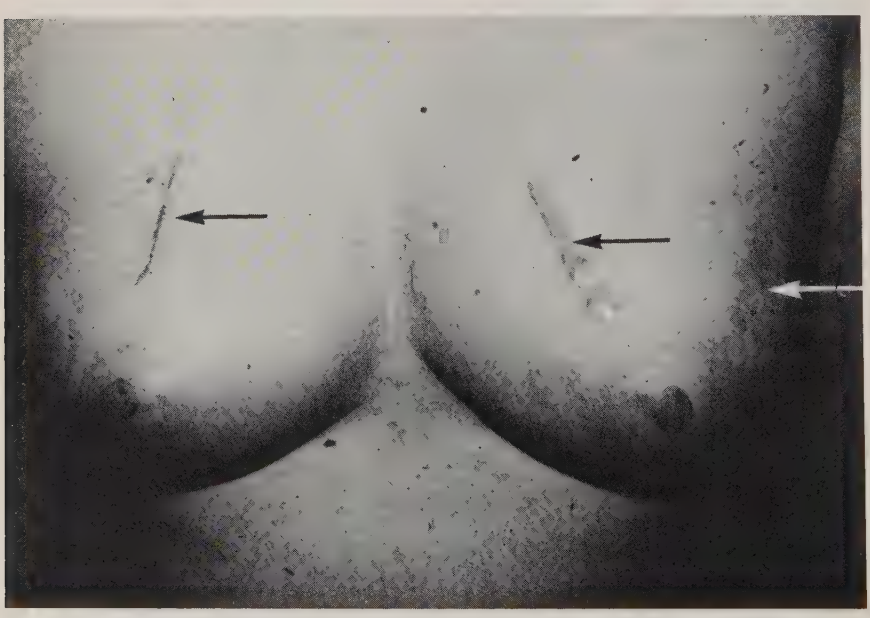

Figure 11. Ugly radial scars following the excision of several cysts.

The use of radial incisions in the breast, despite their popularity and prevalence, is subject to argument. The usually quoted reason for their use is to avoid damage to the ducts, whereas the ducts in the adult breast may be transected with impunity. Elsewhere in the body, surgeons strive to place incisions following the natural skin lines (Langer's line) which are guides to the normal tension in the skin. Incisions made at right angles to these lines may gap, and the scars are likely to broaden and hypertrophy (Fig. 11). Incisions made parallel to or within these lines tend to fall together and result in more aesthetic, almost invisible scars. This author, therefore, follows Langer's lines in the breast (Fig. 8) when planning incisions, especially if the lesion for which operation is anticipated, is clinically benign.

If biopsy discloses a cystic lesion, it is opened and the inner surface inspected to make sure it is not a cystic papillary carcinoma or a circumscribed (medullary) carcinoma with cystic changes. If the cyst is large, it is not necessary to remove it in toto. Excision of a section of the wall with a small portion of contiguous breast parenchyma usually suffices.

FOLLOW-UP

The aim of all physicians who see patients with symptoms of breast disease should be to follow these patients systematically, so that carcinoma, should it develop, may be detected in an early stage. However, this ideal is almost impossible to accomplish because of the limitations of time and the number of physicians available. Women without a predisposition toward carcinoma should be examined at least annually. If ancillary techniques such as mammography and thermography ultimately prove feasible as screening aids, they should be utilized in addition to clinical examination.

Women who are predisposed toward the development of mammary carcinoma deserve special consideration and more careful follow-up. Women with a family history of breast carcinoma should be examined at least twice annually after the age of 35. Women with past history of carcinoma of one breast, with a history of gross cystic disease, with a history of multiple intraductal papillomata, or with a history of lobular neoplasia or lobular carcinoma-in-situ should be examined at 3 month intervals for the remainder of their lives, starting from the time they first develop the disease which predisposes them to carcinoma.

SUMMARY

The ubiquitous problem of mammary carcinoma has been publicized increasingly in both scientific and lay publications in the past decade, both because of an apparent increase in incidence and because of raging controversies regarding optimal therapy. No new curative methods of treatment for breast cancer have been found during the present century. Surgery and irradiation remain the only curative weapons, with irradia-

tion being, at best, a poor second choice. If patient survival is to be improved, increased efficiency at earlier detection must be realized, in addition to the continued search for new avenues of therapy. Planned educational programs for prospective patients are essential, as well as improvements in the clinical teaching of physicians. Until the nemesis of breast cancer has been eradicated, it behooves all physicians who care for patients with breast disease to continue to collect detailed and accurate clinical data regarding their patients, to classify each patient encountered according to the clinical stage of disease when therapy is begun, and finally to accumulate survival data for all patients treated by whatever methods are chosen. Screening programs employing combinations of techniques, such as thermography, xerography, and clinical examination should be encouraged and supported to determine if they will not only detect carcinoma in its earliest stages, but also identify the women in whom it may already exist in a preclinical state.

When devoted teams of physicians encompassing all disciplines of modern medicine – surgery, medicine, and radiation therapy – will cooperate with one another, using all the techniques which twentieth century science can provide, the final conquest of this formidable threat will be that much closer at hand.

ACKNOWLEDGMENT

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The Clinical Application of Flexible Fiberoptic Colonoscopy

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The physician has always had an irresistible itch to peer deeper and deeper into every body orifice. The first soothing scratch, since the development of the sigmoidoscope 75 years ago, came from the introduction of flexible fiberoptic endoscopy in the early 1960's.

The first working fiberoptic gastroscope was developed in 1963. Subsequently, fiberscopes became available to inspect the lumina of the esophagus, bronchi, heart, and great vessels. In early 1969, after a number of years of research, the first flexible fiberoptic colonoscope was introduced clinically in Japan. By late 1969, production models of the instrument were available in this country.

Since 1969, we have been using the flexible fiberoptic colonoscope (Olympus Model No. CF-MB), attempting to determine its feasibility, capabilities, reliability, hazards, precise indications, contraindications, and the expense-yield ratio in the diagnosis and management of colonic disorders. The description of our methods and experiences should clarify these considerations for the reader.

TECHNIQUE

Preparation

Colonoscopy, unlike fiberoptic endoscopy conducted in air or clear liquid media, is performed in a hostile environment that may contain opaque fluid and solid fecal matter. Straight tubular sigmoidoscopy allows aspiration and removal of solid debris, but the small-caliber suction channel of the colonoscope permits removal of only clear fluid, free of particulate matter. Fecal debris, when in contact with the viewing lens, not only interferes with vision but produces a residual opalescent haze on the lens. Any impediment to the lens system which cannot be cleared

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with the lens washer, or any clogging of the aspirating system necessitates complete withdrawal of the instrument for cleansing. When this occurs, after arduous labors have succeeded in introducing the instrument almost to its full length, it is understandably a disappointment.

It is imperative that the colon be cleansed *thoroughly* before the examination is begun. At most, the colon should contain only clear or cloudy fluid. We have used an expensive imported colon lavage machine to flush the colon immediately before examination. This machine introduced 6 to 7 liters of tap water and performed effectively. There were two serious disadvantages in utilizing this apparatus. The first was the necessity of having a registered nurse operate the lavage machine, and simultaneous scheduling of the machine, the nurse, and the patient became a difficult matter. Secondly, only tap water could be used for the lavage and posed the hazards of hyponatremia and hypokalemia. These drawbacks led to the abandonment of the device.

In an attempt to reduce ancillary personnel to a minimum, we evolved a satisfactory routine of preparation. We have prescribed one bottle (240 cc.) of citrate of magnesia nightly for 3 nights prior to the colonoscopic examination and adherence to a liquid diet for 48 hours before the procedure; a high colonic irrigation with physiologic saline solution on the eve of the examination and again at least 2½ hours prior to the examination. This time interval between the last high colonic irrigation and examination is necessary to avoid retention of excess fluid in the colon. Breakfast is withheld when the procedure is conducted before 11:00 A.M.; a liquid breakfast is allowed when conducted at a later hour. The patient should be in a fasting state for at least four hours.

Colonoscopy is no more uncomfortable than sigmoidoscopy, but premedication is helpful in reducing the motor activity of the colon. We have used Lomotil (diphenoxylate hydrochloride with atropine sulfate) for the past 10 years to lessen bowel contractility during proctosigmoidoscopic examinations, and have applied this drug to colonoscopy. Two tablets of Lomotil are given the night before the examination, and the dose is repeated 2 hours before the procedure begins. Meperidine hydrochloride (Demerol), hydroxyzine hydrochloride (Vistaril), and atropine sulfate are administered by hypodermic 1 hour prior to the examination in doses that suit the size and physiologic tolerance of the patient. Sedation during the examination is required only if polypectomy is carried out, an eventuality that will be discussed later. Several authors have described the use of intravenous diazepam (Valium) to the point of stupefaction as a method of conducting the procedure, but we have found this unnecessary and theoretically hazardous. Intravenous diazepam is used only during polypectomy and then in moderate dosage.

The procedure is accompanied by a sense of abdominal fullness and mild colic. It is wise to keep the patient mentally clear so that he can relate his discomfort, which can then be relieved by engaging the aspirating action of the instrument. The state of consciousness of the patient allows the physician to assess any untoward physiologic responses which might result from excessive intra-abdominal pressure or fluid and electrolyte imbalances resulting from colonic preparation.

Place

Initially, colonoscopy was performed in the radiology department so that fluoroscopic guidance could be available and radiographic films of the abdomen could be taken for corroboration. Several serious disadvantages soon became evident. The amount of radiation exposure to the examiner gave rise to considerable concern, and discoloration of the fiberoptic bundles was reported by some workers. Experience and the development of more mobile tips for the colonoscope allowed passage and manipulation through the most acutely angulated passages of the colon without fluoroscopic assistance. Using the fluoroscopic room in the radiology department also taxed the ever present cordiality of the radiologist, since colonoscopic examinations had to be scheduled around the radiographic procedures. In addition, it seemed impractical to subvert highly expensive hospital real estate unnecessarily.

By evolution, we moved the procedure quite satisfactorily to a room ordinarily devoted to sigmoidoscopy. The only absolute requirements are that there be a comfortable examining table, ample room for the equipment, adequate suction, and a commode for the patient. Our regimen has become completely independent of roentgenographic assistance. We rarely need to confirm the position of the end of the colonoscope by roentgenography, but should this be necessary a single portable radiograph suffices.

Simplification of the entire procedure should be the goal. It is realistic, of course, to expect that some degree of experience with the instrument will be needed before complete self-reliance is gained.

Performance

The patient is placed in the right Sims's position simply because it is easier to arrange our equipment. Prior to introducing the colonoscope, all systems of the instrument must be checked. It should be affirmed that the lens is clear and that the focus of the optical system is satisfactory to the eyes of the endoscopist. The lens-washing system should be tested because this sometimes becomes nonfunctional if clogged with small particulate matter. The mobility of the tip is demonstrated, and the endoscopist reacquaints himself with the relative motion of the controlling mechanism and the tip of the instrument.

The anal canal is well lubricated with the examiner's gloved index finger and the tip of the colonoscope is lubricated with a water-soluble lubricant. The speculum provided for the introduction of the instrument is not required. The tip can be passed gently, and usually without discomfort, through the anal canal. Advancement of the instrument proceeds thereafter under direct visualization of the lumen. A glove encases the right hand of the endoscopist; the head of the instrument is held in his left hand. The index finger of the left hand may introduce air, wash the lens, or produce suction by pressing the appropriate button as the need arises. Other fingers of this hand manipulate the handle controls. These instructions will vary somewhat with the make of the instrument but, in general, the manipulations can be managed with the left hand. During difficult maneuvering an assistant may hold the throat of the instrument

Figure 1. The colonoscope doubled over upon itself in rectum brings the shaft of the instrument into view.

so that the examiner's left hand is free to manipulate the tip control without restriction.

The right hand introduces the colonoscope, rotating it as becomes necessary. Rotation of the instrument on its longitudinal axis is frequently helpful and adds another dimension in motion which will allow the tip to be placed appropriately for optimal advancement. Generally, in the region of the rectosigmoid, an acute angulation is encountered that requires additional care for passage. The instrument may have to be alternately advanced and withdrawn until the lumen can be completely appreciated and the instrument appropriately maneuvered. Such intermittent withdrawal and advancement of the instrument is a well known technique in sigmoidoscopy and is similarly applicable here. At times, retraction of the instrument for 20 cm. or 30 cm. allows the straightening out of convolutions, making further advancement easier.

It may be necessary at some point of acute angulation to engage in a maneuver that is considered bad form in sigmoidoscopy, i.e., the instrument may have to be forced when the lumen is not completely in view. This can be done safely so long as one sees the mucosa sliding past the tip of the instrument. Keeping the hooded tip in an unlocked position allows the flexibility of the instrument to respond to the curves of the bowel. This flexibility is not present in the straight-tubed sigmoidoscope. Newer and more versatile instruments make it unnecessary to use an endotracheal cuff as previously advocated by Shinya.[4] Forcible introduction without observing the lumen in the rectum may produce a doubling of the instrument upon itself, and the endoscopist may find the body of the colonoscope in his view (Fig. 1). Acute angulations and fixations, whether anatomic, inflammatory, or postoperative, may prevent com-

plete introduction of the instrument. There is usually a relationship between the amount of time, patience, and skill of the examiner and the length of colonoscope introduced. On occasion, there may be an insurmountable impedance and it becomes simply a matter of judgment as to when the examiner desists.

From the moment the instrument is introduced it becomes evident that the examination is being conducted in a dynamic organ, and all factors capable of reducing motor activity should be brought into play. Sufficient air should be introduced to keep the bowel lumen open, but periodic decompression of intracolonic pressure may actually encourage quieter motor activity. It should be remembered that the length of instrument introduced has little bearing upon advancement of the tip, and that the distances noted on the colonoscope are relative and not absolute. The levels at which lesions are indicated on the instrument vary according to the configuration and motor activity of the colon. A lesion observed at the 50 cm. level may be noted, after manipulation of the instrument, at either the 65 cm. or the 35 cm. level.

The lumen is inspected carefully as the instrument is withdrawn, and a to-and-fro motion may be required to visualize the entire circumference. Only once did removal of the instrument present a problem when, because of a tight corkscrew configuration, traction of some moment was necessary to effect the colonoscope's release (Fig. 2).

Figure 2. The corkscrew configuration associated with perforating carcinoma which causes difficult removal of colonoscope.

Examination can be supported by color photography. On the manufacturer's recommendation, we used Ektachrome EHB 20 film which allows 40 single-frame exposures. Adaptation of a Super 8 motion picture camera is possible using the same light source, and 16 mm. motion picture photography can be achieved with special additional lighting arrangements.

Biopsy, when indicated, is performed without difficulty. Introduction of the biopsy forceps through the biopsy channel does not present a technical problem, although acute angulation of the tip of the colonoscope may cause some difficulty in passing the forceps through the last 15 cm. of the instrument. Since the biopsy forceps must be accommodated in a 2.5 mm. channel, the small jaws of the forceps limit the size of the biopsy specimen, which is usually not greater than 1.5 mm. in diameter. We have encountered no particular hazards with the biopsy forceps. Perforation should be a most unlikely possibility, and the bleeding that results from so small a biopsy defect should not pose a problem.

Following removal of the instrument, relief to the patient may come with forceful digital rectal manipulation which flattens the levator ani and allows expulsion of any excessive gas remaining from the procedure.

CLINICAL INDICATIONS

Only extensive experience can provide the examiner with the data necessary to recognize the clinical states in which the colonoscopic examination will be most or least informative. A certain spirit of adventure tempered with sound medical judgment and common sense may lead to special clinical and academic applications yet unappreciated. An expansive list is offered with the full expectation that continued modification shall be in order.

Inflammatory Diseases

Because inflammatory diseases of the colon have so often been beyond the visual reach of the endoscopist limited to a 25 cm. long straight tubular sigmoidoscope, it is natural that he look forward to direct inspection and biopsy of abnormalities heretofore closed to his view. His curiosity must be tempered with caution, for colonoscopy may be hazardous in the presence of acute inflammatory disease. Good medical practice demands that areas of bacterial inflammation or cellulitis not be needlessly manipulated. Preparation of the colon for colonoscopy requires stringent purgation and irrigations that are contraindicated in the presence of severe inflammatory disease of the gastrointestinal tract. The physical introduction of the colonoscope and the associated increased intraluminal pressure should be avoided except in the mildest inflammatory processes. Instances of acute toxic megacolon complicating acute ulcerative colitis have been reportedly precipitated by flexible fiberoptic colonoscopy.

There are, nonetheless, inflammatory lesions that lend themselves to cautious colonoscopic examination performed at the propitious time. Lesions in this category include (1) diverticular disease, including diver-

ticulitis and peridiverticulitis; (2) ulcerative colitis, with or without stricture development; (3) transmural (granulomatous) colitis; (4) radiation proctitis and sigmoiditis; (5) pneumotosis cystoides intestinalis; and (6) miscellaneous kinds of colitis.

Diverticular Disease of the Colon

Diverticula and the various manifestations of diverticular disease are ordinarily well demonstrated radiographically; and in most clinical circumstances colonoscopy is not necessary. However, several interesting facts have become clear. More diverticula are noted colonoscopically than by x-ray examination, and this is understandable since the colonoscopic examination is accompanied by the introduction of air into the colon. The radiograph, it seems, characteristically minimizes the intensity of the inflammatory process, for in many instances acute changes of an unexpected nature have been noted. Nuances evidently can escape the radiologist. Re-emphasis must be made that colonoscopy performed in the presence of active infection may be dangerous.

The major value of colonoscopy exists where distinction between diverticulitis and carcinoma cannot be made roentgenographically. Ordinarily, when the distortion of diverticular disease has advanced to where the two diseases are indistinguishable, surgery is indicated. On several occasions, where a presumptive diagnosis of cancer was made in patients who were serious anesthetic and surgical risks and in whom nothing less than a carcinoma could demand the acceptance of the hazards of an operation, diverticulitis was established endoscopically, and surgery with its attendant risks avoided. Curiously, the radiographic appearance of mild diverticular changes in combination with a polyp strongly suggests cancer, and the importance of this discovery is enormous, particularly in poor risk patients. An element of caution is demanded with the realization that a perforating carcinoma may offer only the inflammatory changes to the endoscopic view. Once again, we are reminded that a negative endoscopic examination is not an absolute indication that cancer is not present.

The colonoscopic appearance of diverticulitis and peridiverticulitis is characteristic. The mucosa is edematous. Polypoid folds and excrescences, even to the point of bullous edema, may be noted. Some degree of friability is present and submucosal fibrosis and a sense of stiffness of the bowel wall may be appreciated. Heavy mucoid and purulent material may be in the lumen and frank pus has been seen escaping from a small intramural abscess.

Diverticular disease, as a source of acute massive hemorrhage, does not lend itself to colonoscopic examination because of the disturbed visibility owing to the presence of large quantities of intraluminal blood. Chronic intermittent gross bleeding has been noted to arise from diverticular changes with extreme friability despite an unremarkable barium enema examination.

CASE 1. A 68 year old obese white woman had noted over a 9 month period colicky lower abdominal pain associated with passage of blood per rectum. Repeated barium enema examinations indicated the presence of mild diverticular disease of the mid-sigmoid colon. Colonos-

copic examination was requested to determine the origin of the bleeding. Colonoscopically at the 35 cm. level marked edema of the mucosa associated with friability, and unrelenting spasm was noted. These changes were far more severe than was suggested by the roentgenogram. Sigmoidectomy was recommended and following surgery, during a brief period of clinical observation, abdominal pain and bleeding did not recur.

Ulcerative Colitis

Colonoscopy in *acute ulcerative colitis* has very limited application. When the serious risk of acute toxic megacolon as a consequence of performing the study in this disease is weighed against its clinical usefulness, the examiner must have a substantial reason for accepting the hazard.

In the prosaic form of ulcerative colitis, aside from academic interest, colonoscopy generally serves no useful purpose. When there is a normal rectum but radiography discloses nonspecific changes in the mid-sigmoid colon or beyond, colonoscopy may be diagnostic.

CASE 2. G. R., a 19 year old student, had colicky abdominal pain, bloody diarrhea and weight loss. A barium enema examination revealed minimal inflammatory changes involving the mucosa of the descending colon. A normal proctosigmoidoscopy and mucosal biopsy of the rectum were performed. Colonoscopic examination revealed an abrupt change of the mucosa at the 60 cm. level with friability and superficial stellate ulcerations and fibrinous exudate. Colonoscopic biopsy led to the microscopic diagnosis of nonspecified ulcerative colitis.

The ever-present need to detect a cancer developing concomitantly with ulcerative colitis is not, in our opinion, made easier by colonoscopic examination. Contrary to the views of those who have suggested that a differential diagnosis can be made between the benign and the malignant stricture of *chronic ulcerative colitis*, we feel that the results of colonoscopy may be misleading. The malignancy that develops along with ulcerative colitis is generally intramural with minimal mucosal involvement, and is not recognized easily by gross mucosal inspection. The biopsy one takes with the colonoscopic forceps is very shallow, so that the intramural cancer may not have been reached. Furthermore, a biopsy of pseudopolyps that is negative for cancer also cannot be construed as proof that cancer does not exist, since the cancer complicating chronic ulcerative colitis does not arise in the pseudopolyps but in the intervening reparative mucosal zones. Neither the colonoscopic examination nor the colonoscopic biopsy can exclude a malignancy in chronic ulcerative colitis which is associated with stricture development. This condition must continue to be viewed as a frank indication for colectomy.

Transmural Granulomatous Colitis

Transmural or granulomatous colitis quite frequently involves the colon beyond the reach of the rigid sigmoidoscope. The flexibility and greater penetrative capabilities of the colonoscope may allow inspection and diagnosis when the radiographic diagnosis is not quite clear. We have not had a sizeable experience with this disease but would suggest its application in the instance of the patient with repeated perianal abscesses in whom there is a suspicion but no diagnostic proof of transmur-

al colitis. Limited clinical information has been gained by inspection of the colon at the site of an ileosigmoidal fistula secondary to regional enteritis involving the terminal ileum but so far practical implications are few.

Radiation Proctitis and Radiation Sigmoiditis

Radiation proctitis and sigmoiditis are generally associated with fixation, rigid deformities, and extreme patient discomfort which limit inspection by sigmoidoscope to the rectal ampulla. The status of the bowel beyond the rectosigmoid can be determined only with a flexible fiberoptic instrument. So long as the lumen is 1.2 cm. in diameter the instrument can be accommodated. The following illustrates its unusual diagnostic potential.

CASE 3. A 67 year old woman was treated with intracavitary radium for adenocarcinoma of the endometrium, because technical considerations prevented hysterectomy. Treatment was followed 10 months later by diarrhea and roentgenographic demonstration of a 3 cm. long constriction at the terminal sigmoid colon. Sigmoidoscopy revealed mild radiation proctitis with early superficial ulceration, friability, and submucosal fibrosis, but the instrument could not be introduced beyond the rectosigmoid because of angulation and fixation. With the flexible fiberoptic colonoscope it was possible to pass beyond the angulation into the distal sigmoid, where a lumen filled with gray-white necrotic tissue was visualized. This finding indicated that the area of stenosis was frank radiation necrosis in imminent danger of perforation. Combined abdominotranssacral proctocolectomy, proctocolostomy, and hysterectomy were performed for what was revealed to be an area of circumscribed necrosis at a point where the sigmoid colon fused with the fundus of the uterus (Fig. 3).

Pneumotosis Cystoides Intestinalis

Pneumotosis cystoides intestinalis has been seen with increasing frequency over the last several years, and colonoscopic examination is often the only manner in which the roentgenographic picture can be corroborated. In many instances the diagnosis is quite apparent, but there are instances in which a differential diagnosis between granulomatous colitis and pneumotosis cystoides intestinalis can be difficult. Six cases of pneumotosis cystoides intestinalis have been examined colonoscopically since 1969, and the appearance of the bowel is somewhat different than many authors indicate. The submucosal tumefactions can vary from very small (several mm.) elevations to polypoid intrusions upon the lumen measuring several cm. in diameter. The suggested classical description of clear, gas-filled cysts has not ordinarily been noted, and most frequently there has been an element of submucosal fibrosis producing an opaque quality to the mucosa. Friability to the point of gross bleeding has also been visualized.

Miscellaneous Forms of Colitis

Clinical situations of diverse presentation have led to the appreciation of colonoscopically nonspecific, unlabeled forms of colitis, some of which may be completely unexpected. The endoscopic appearance can

Figure 3. Case of A. P.—Roentgenogram suggesting merely stenosis (*A*). Correct diagnosis of radiation necrosis established colonoscopically. Surgical specimen showing radiation injury of sigmoid (*B*).

vary through the spectrum of mild edema to mural fibrosis with or without friability, punctate hemorrhages, and ulceration. Many of these states represent specific and nonspecific infectious colitides. There are instances where the early manifestations of ulcerative colitis are neither endoscopically nor microscopically diagnostic. Ischemic colitis, particularly in the fibrotic stage, may account for some of the unlabeled colitides seen.

Colonic Hemorrhage

The mucosa cannot be viewed satisfactorily if a large amount of blood and feces is present in the lumen. It is, therefore, unlikely that colonoscopic examination has value in massive hemorrhage. In the presence of mild hemorrhage or blood admixed in the stool, or when mucus and blood are noted in the lumen beyond the reach of the sigmoidoscope the colonoscopic examination serves its most useful purpose. Colonoscopy has established the presence of a large number of polyps, benign and malignant; cancer; diverticulitis; and various colitides as sources of bleeding when barium enema examination has not been diagnostic.

Colonoscopic examination is absolutely indicated in any individual with blood marbleized in the stool, or when blood and mucus are noted in the bowel lumen and there has been no positive diagnosis made by roentgenography. To what extent colonoscopic examination should be included in the routine investigation of patients with microcytic anemia and occult blood in the stool but whose roentgen findings are normal has yet to be determined, and will probably be disclosed by wider experience.

Cancer

Proctosigmoidoscopy and barium enema examinations remain the primary methods for diagnosing adenocarcinoma of the colon. Colonoscopic examination is too costly to be used as either a screening procedure or a routine method of investigation. In cases where the symptoms and signs indicate that cancer is a reasonable probability, but sigmoidoscopic and barium enema examinations are negative, the symptoms and signs should be weighed as possible indications for colonoscopy. Blood marbleized in the stool and gross bleeding without apparent cause should label the patient as a cancer suspect.

CASE 4. A 56 year old white man was extensively studied for intermittent rectal bleeding associated with anemia, colicky abdominal pain, and radiolucencies noted on x-ray of the skull. Complete roentgenographic survey revealed no primary neoplasm. These studies included two separate barium enema examinations and a selective arteriogram. Flexible fiberoptic colonoscopic examination, however, revealed a 4 to 5 cm. in diameter polypoid mass in the region of the splenic flexure at the 75 cm. level with the characteristics of an adenocarcinoma. Biopsy confirmed the diagnosis of adenocarcinoma and subsequent partial colectomy was performed. The radiolucencies noted in the skull were presumed to be venous lakes (Fig. 4).

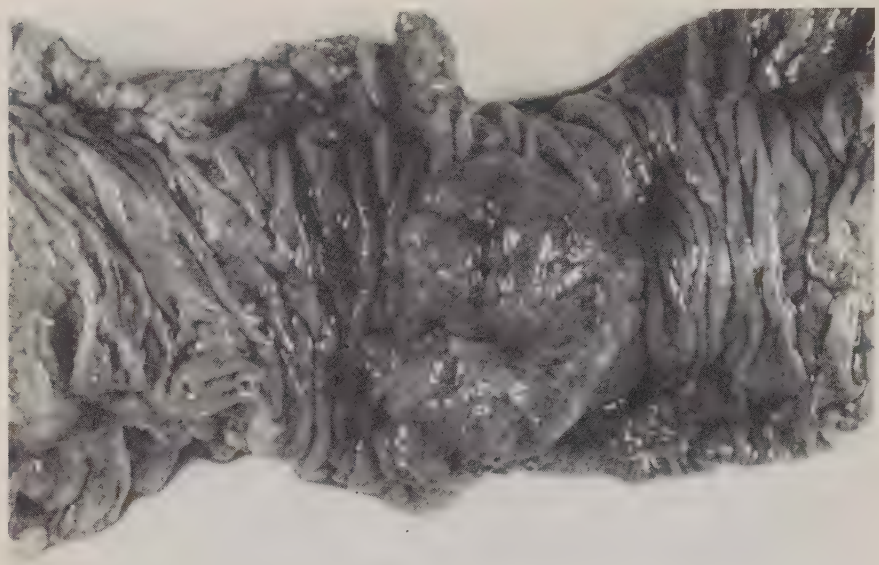

Figure 4. Case of R. S.—Large polypoid carcinoma of splenic flexure diagnosed colonoscopically after several "negative" barium enema examinations.

Figure 5. Recurrent extramural carcinoma of colon with ileal involvement and penetration of left iliac artery adventitia despite both a normal mucosal pattern on barium enema examination and flexible fiberoptic colonoscopic inspection.

Suture-Line Recurrence of Malignancy

Following resection of the colon for malignancy, recurrence of carcinoma at the suture line is a realistic consideration. Examination of anastomotic sites within reach of the sigmoidoscope is ordinarily part of the routine follow-up in resections of the rectum and distal sigmoid. When the resection and anastomotic sites are beyond the reach of the sigmoidoscope, one should depend upon radiographic discovery. Although the colonoscope now allows for direct inspection of the anastomosis, this has not become routine procedure, nor should it. Colonoscopy is warranted only when there are suggestive symptoms or radiographic indications of recurrence. Experience has shown that an abundance of extramural tumor may be present despite a visibly normal area of anastomosis (Fig. 5).

On occasion, barium enema examination of a poor-risk patient has shown fairly conclusive evidence of a carcinoma. The patient, his family, and his physician are reluctant to resort to colonic resection with anything short of an absolute diagnosis. This situation requires cautious judgment and colonoscopic examination may be used for confirmation but it is rare to establish the diagnosis in this way. Ordinarily, if the deformity seen by roentgenography is so severe that it indicates the likelihood of cancer, resection usually cannot be circumvented. In the case of the poor-risk patient an appropriate option, in the absence of carcinoma, may be in order as referred to in the discussion of diverticular disease.

Removal of Foreign Bodies

Most foreign bodies entering the gastrointestinal tract will pass through the colon if able to negotiate the terminal ileum. In the presence of a rigid deformity resulting from disease or previous surgery the foreign body may not be able to pass.

Case 5. A 41 year old woman was being examined colonoscopically prior to planned colostomy closure following combined abdominotranssacral proctocolectomy and proctocolostomy for an irradiation injury when a white cylinder was unexpectedly noted intraluminally. The patient had recalled having lost into the colostomy the plastic gasket of an irrigating device five months before. The postoperative angulation of the colon prevented passage of the foreign body. The colonoscope was introduced and attempted removal per anus was unsuccessful with balloon catheter intubation but after some difficulty the gasket was manipulated proximally for recovery through the colostomy, avoiding laparotomy (Fig. 6).

Polypoid Disease

The area of greatest impact of colonoscopy is upon polypoid disease of the colon. The colonoscope functions in four areas: (1) diagnosis, (2) definition, (3) judgments and management, and (4) polypectomy.

Traditionally, we have relied upon radiography for the diagnosis of polypoid lesions of the abdominal colon. A large number of polyps have been overlooked radiographically but clearly diagnosed by colonoscopy. These polyps have been both benign and malignant, pedunculated and sessile. In 50 per cent of individuals who harbor one radiographically

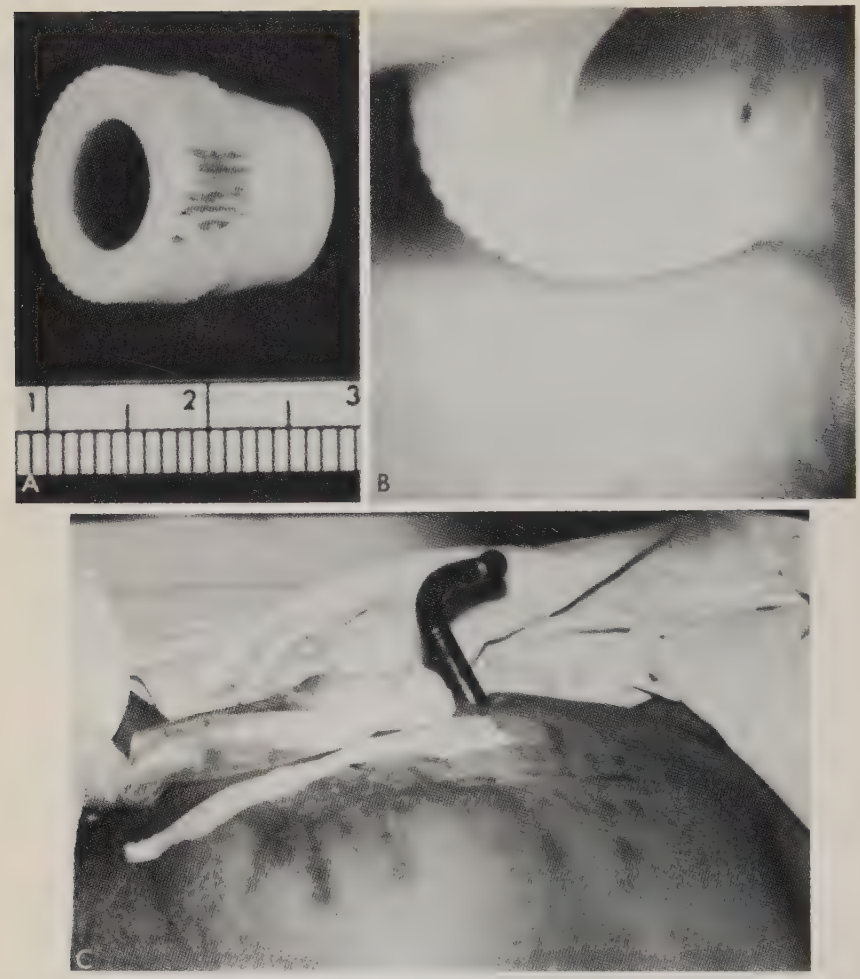

Figure 6. Foreign body—plastic enema gasket (*A*). Colonoscopic view of plastic disposable enema gasket lost in distal colon (*B*). Retrograde colonoscopic removal of foreign body (*C*).

diagnosed polyp, we have found at colonoscopic examination one or more additional polyps.

When one realizes that quite large polyps and polypoid cancers can be missed completely by radiography it is unrealistic to expect accurate detail and definition of all polyps noted. The clinical implications of a sessile polyp and a pedunculated polyp are quite different, yet there have been numerous instances in which pedicles were described which did not exist. "Pedunculated" polyps have been followed roentgenographically for years, only to have the endoscopist discover, at the time of proposed colonoscopic polypectomy, that no pedicle was present. In one case, the lip of a crater-like carcinoma was regarded radiographically as a well-established pedicle (Fig. 7). Radiographic observation was selected rather than colectomy, resulting in considerable and unfortunate delay.

The biopsy of a polyp through the colonoscope with a benign result does not mean that a carcinoma has been ruled out, and should rarely be an indication for less than active therapy. An occasional exception to this rule is the case of multiple negative biopsies used as justification for not performing resection in a patient whose serious medical problems provide strong deterrents to the risks of anesthesia and surgery.

Transabdominal colotomy and polypectomy have customarily been accompanied by operative coloscopy. Insertion of a sterile sigmoidoscope

Figure 7 Barium enema roentgenogram with shadow interpreted as pedicle of polyp (*A*). Specimen of palliative resection after 7 mos. delay showing the exaggerated lip of crateriform carcinoma which produced the misleading radiographic shadow (*B*).

Figure 8. Specimen indicating 8 polyps, one of which was carcinoma in situ. Multiple barium enema examinations had indicated only a single polyp in sigmoid colon.

into one or more colotomy sites during laparotomy was prompted by the high incidence of polyps unrecognized by barium enema examination.[1] Flexible fiberoptic colonoscopy done preoperatively allows an adequate inspection of the colon without incurring the disadvantages, inconvenience, and theoretical hazards of contamination and prolonged operative time imposed by operative coloscopy.

Certain critical surgical judgments depend upon the number, type, and distribution of multiple polyps. The colonoscopic disclosure of this qualifying information may allow judgments to be made preoperatively, avoiding operative indecision and coloscopy. A case in point is the instance of a 47 year old man who, upon radiographic examination, was found to have what appeared to be a single pedunculated polyp of the sigmoid colon. At colonoscopy, in addition to this lesion, two sessile polyps were seen in the splenic flexure. This immediately indicated the need for partial left colectomy. At laparotomy, with the colonoscopic information at hand, the appreciation of still another soft sessile polyp in the cecum made the judgment for subtotal colectomy easier. The operative specimen contained a total of eight polyps, one of which contained an in situ carcinoma (Fig. 8).

POLYPECTOMY

Colonoscopic polypectomy is a logical outgrowth of colonoscopy, and the method is adapted from the procedure involving an electrosurgical wire snare technique originally described for gastric polypectomy.[3] The use of this snare, while generally practical, had certain features which were less than completely satisfactory. Manipulating the

Figure 9. Electrosurgical colonoscopic polyp snare.

snare over the head of the polyp was frequently not precise, difficulty was encountered in placing the snare over polyps with large heads, it was often difficult to release the snare to change the site of application, and in the event of electrical current failure it was occasionally impossible to remove the snare (Fig. 9).

These features led the senior author to develop a scissors-type electrosurgical polyp forceps suitable for colonoscopic polypectomy (Fig. 10).[2] This device consists of three components: a double-bladed dull-edged approximating tip, a single-wire Teflon-encased shaft, and a handle for conducting the required electrosurgical current and for manipulating the blades. Sliding the finger rings of the handle produces the longitudinal motion of the wire through the Teflon sheath which, in turn, produces the scissor action of the blades. We have, for the most part, used the polyp forceps for polypectomy but will, depending on the problem at hand, use either method to our satisfaction.

Colonoscopic polypectomy is reserved for polyps with well-defined pedicles originating in the colon beyond the reach of the rigid sigmoidoscope. We limit polypectomy to those lesions within reach of the 105 cm. flexible fiberoptic colonoscope, and this ordinarily means that polyps proximal to the distal transverse colon are not treated with this instrument, although the longer 188 cm. model permits similar management to the region of the cecum. Polyps with broad pseudopedicles and sessile polyps are not suitable for colonoscopic polypectomy principally

Figure 10. Electrosurgical, scissor-type colonoscopic polyp forceps of the senior author's design (*A*). Instrument in its entirety (*B*).

because of the hazard of perforation of the wall of the colon. The incidence of malignancy being greater with sessile polypoid lesions requires an additional element of caution. Lastly, very small sessile lesions can be destroyed by electrocoagulation after adequate biopsy (Fig. 11).

Proper precautions regarding the grounding of electrical equipment must be taken. These are usually described in the manufacturer's instruction manual.

The suggestion that the colon be flushed with carbon dioxide to prevent explosion is not mandatory since room air is constantly in-

troduced into the colon prior to the procedure and would adequately dilute any combustible gas.

Preparation

Preparation of the colon for polypectomy is similar to preparation for diagnostic colonfiberoscopy. Citrate of magnesia, 240 cc., is given nightly for 3 nights and a full liquid diet is followed for 2 days before examination. Antibiotic bowel preparation is not considered necessary and systemic antibiotics are not given, although the patient is otherwise prepared for anesthesia and laparotomy should they be necessary.

The theoretical hazards of perforation and bleeding requiring emergency laparotomy require special consideration in view of the fact that colonoscopic polypectomy is a new procedure and the forensic implications are without precedent. For these reasons, the patient is thoroughly evaluated from a medical standpoint and the patient is informed that electrosurgical perforation of the colon and hemorrhage are inherent risks of the procedure. This represents supreme caution on our part but we think it advisable for the moment even though we have experienced neither problem to date.

Sedation similar to that preceding diagnostic colonoscopy is given; i.e., two tablets of Lomotil on the eve of the examination and again on the morning of the procedure. Demerol, atropine, and Vistaril are given by injection 45 minutes prior to the procedure in dosages commensurate with the patient's physiologic tolerance.

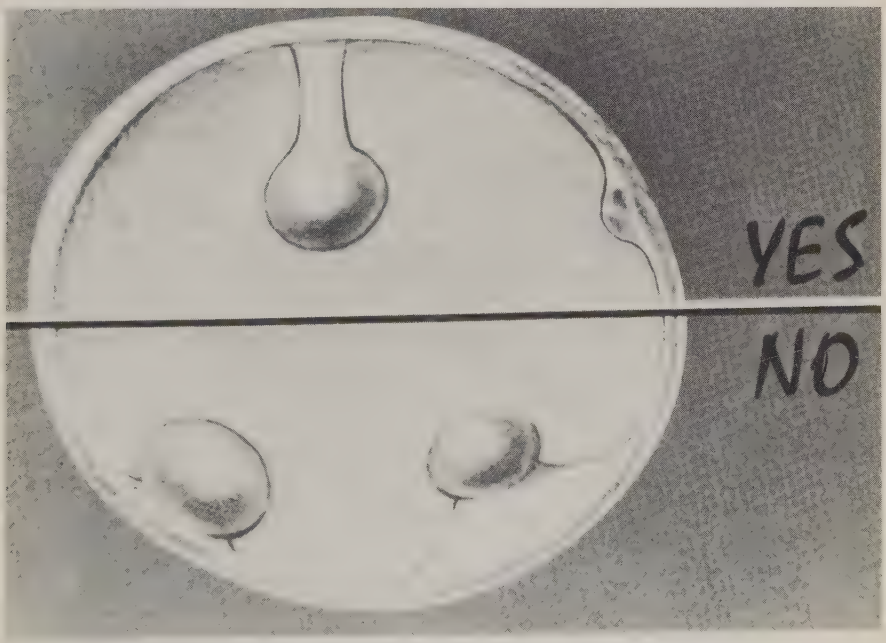

Figure 11. Guide to colonoscopic polypectomy reserved for the pedunculated polyp with a well defined pedicle and the less than 5 mm. sessile polyp which can be adequately biopsied before complete electrofulguration.

Place of Performance

We originally performed polypectomy in the operating room with an anesthesiologist in attendance for the necessary intravenous introduction of diazepam. It became apparent that this was impractical. With the cooperation of the anesthesiology department, we now perform the procedure in the same sigmoidoscopic room used for diagnostic colonoscopy, with the anesthesiologist administering intravenous diazepam for mild to moderate sedation. In addition to the independence one has working outside of the operating room, a sense of urgency is avoided in what may be a time-consuming and tedious procedure.

Technique

Both the electrosurgical colonoscopic polyp forceps and the electrosurgical wire snare are used for polypectomy. By performance, the initial attempt is made with the forceps, which we find easier to apply and reapply as necessary and safer in all respects. We use the snare if the forceps does not provide a satisfactory technical result.

The patient is placed in the right lateral Sims's position which is similar to the position used for diagnostic colonoscopy. It is wise to have the source of electrical current and its connections fully operative prior to insertion of the colonoscope so that polypectomy can be initiated immediately after the polyp is localized. If the patient has not been colonoscoped previously, it is well to insert the entire length of the instrument in a search for multiple polyps, despite the indication of only one polyp by barium enema examination.

As one attempts to secure the polyp with either the forceps or the snare, the colonic motility is truly appreciated and the importance of the preoperative sedation and the intravenous diazepam becomes apparent. The forceps or the snare is introduced through the biopsy channel. Intraluminal pressure should be reduced before introducing either instrument so that fluid does not eject through the opening in the biopsy channel of the instrument handle. If there is an acute angulation of the tip of the instrument, the final 10 to 15 cm. of introduction of the forceps or snare may be difficult. In such an instance the instrument can be withdrawn to a point where the tip of the colonoscope may be straightened and the snare or forceps then introduced up to the working face, after which the colonoscope is reintroduced to the site of the polyp.

Ideally, two assistants to the endoscopist make for a more rapid and safe polypectomy although one assistant will suffice. One assistant standing opposite the examiner can hold the throat of the colonoscope and also hold the instrument at the level of the anus so that it does not move. The endoscopist can then use one hand to manipulate the controls of the colonoscope and the other hand to introduce the snare or forceps and manipulate it. The other assistant manipulates the handle of the forceps or the wire at the direction of the endoscopist.

Forceps

The forceps should be applied at a point on the pedicle midway between the bowel wall and the head of the polyp. Care is necessary to avoid grasping a portion of the adjacent bowel wall with the tip of the forceps.

The tips are approximated forcibly by sliding the rings of the handle, and a bipolar tube-generated cutting current is applied to the tips in short bursts. The coagulation effect is noted initially and the current is adjusted to the required intensity. Complete transsection of the pedicle may be difficult if it is broader than 1 cm. In the event pedicle transsection does not occur the standard colonoscopic biopsy forceps can be introduced after removing the electrosurgical forceps and multiple biting actions at the electrocoagulated pedicle can accomplish the transsection. After transsection the polyp can be aspirated against the face of the tip and recovered with removal of the colonoscope.

If the plane of the pedicle and the jaws of the forceps are parallel, it may be quite difficult to grasp the pedicle. Inability to rotate the forceps in the biopsy channel may necessitate removal of the forceps in its entirety in the hope that reintroduction will find the pedicle and the blades of the forceps rearranged in a manner that now permits proper grasp of the pedicle.

On occasion, a very stout pedicle cannot be severed. In this event, the polyp is allowed to slough, with recovery accomplished by physiologic saline enemas. Our experience indicates that sloughing will occur within 6 to 48 hours. This circumstance represents a disappointment, of course, for in addition to the nuisance of the mechanics of recovery, there is the associated problem of partial autolysis which interferes with the histologic examination.

Snare

A variety of electrosurgical snares applying similar principles is available commercially. Basically, they all consist of a wire housed in an insulating plastic sheath which, in turn, is introduced through the biopsy channel in the same manner as the electrosurgical polyp forceps. As the wire loop is introduced beyond the plastic sheath, bowing occurs, and by manipulating the end of the instrument, the polyp, and the snare, the snare is eventually passed over the polyp to grasp the pedicle. Strangulation of the pedicle for 3 to 5 minutes before applying tube coagulation current decreases the hazard of bleeding. Tightening the wire with the current applied achieves severance and the polyp is removed as described before. Caution is urged against severing the pedicle too close to the bowel wall or grasping and touching the adjacent bowel wall for fear of surgical destruction and possible perforation.

Complications

Careful colonoscopy and colonoscopic polypectomy should be associated with little risk of serious complications although certain rare instances of difficulty are inescapable and inherent in the preparation, procedure, or disease state. We have not experienced any serious problem but there have been untoward reactions pointing to the areas of hazard. In one case, a partial small bowel obstruction associated with metastatic carcinoma was converted to a complete form. Mild transient hypotension, which responded rapidly to intravenous lactated Ringers' solution, has occurred twice and this was attributed to the combination of salt and

water depletion of preparation with the intraluminal gaseous distention accompanying the examination. In another instance, the hypotension was more prolonged and was accompanied by a bradycardia that persisted for an hour. We have been cautious in examining patients with acute inflammatory lesions and have not personally experienced difficulty. We have expressed the need for restraint in acute processes and alluded to the instances brought to our attention of acute toxic megacolon complicating this study with acute ulcerative colitis. It is reasonable to expect that there will arise an instance of coincidental perforation perhaps through a diverticulum despite the diligence and finesse of the examiner. Bleeding and perforation, neither of which have been experienced by us, are calculated hazards of colonoscopic polypectomy and some incidences are probably inevitable even with strict adherence to the precautions outlined.

SUMMARY

Flexible fiberoptic colonoscopy is proving to be the singular significant innovation of many decades in the management of colonic disorders. The full measure of its impact upon the control of polypoid disease of the colon should be no less than startling as more physicians achieve familiarity with and mastery of the technique of colonoscopy and colonoscopic polypectomy.

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